COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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December, 1941

View in boiler plant at Thermoid Company, Trenton, New Jersey

Topping Extension to West Reading Station ▶

Experience with Embrittlement Detector ▶

Combustion Calculations—Blast-Furnace Gas ▶

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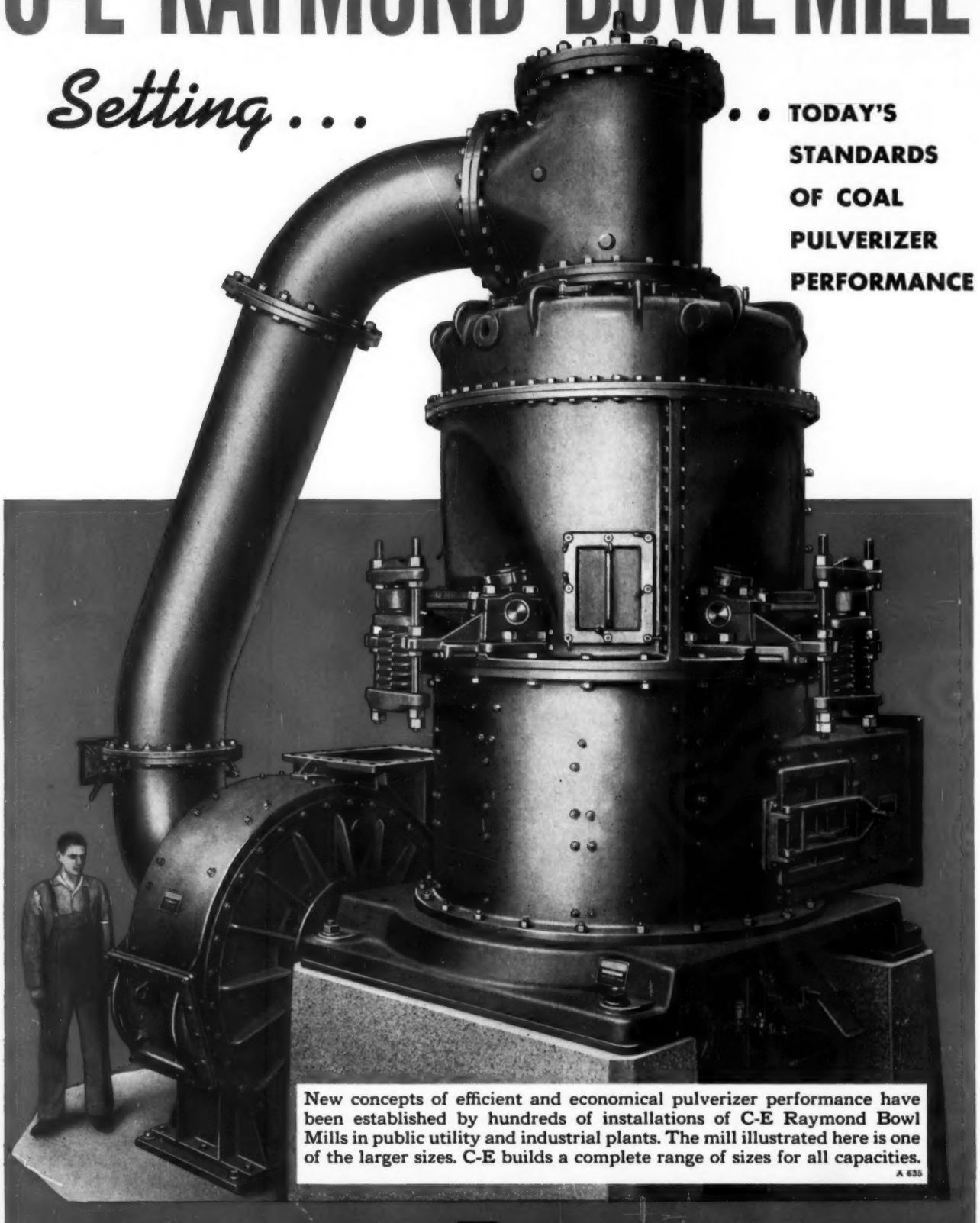

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME THIRTEEN NUMBER SIX

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EDITORIAL

Embrittlement Detection

Few problems in the power plant field have been the subject of as intensive research over a long period as has the intercrystalline cracking of boiler steel, commonly referred to as caustic embrittlement. This problem first came into prominence some twenty-five or thirty years ago following a number of failures in riveted seams of boilers fed with waters containing caustic soda. The phenomenon was encountered both here and abroad and was then ascribed by some to mechanical punishment of the metal during fabrication and by others to chemical causes, both of which may have been contributing factors. But as fabrication technique improved the problem persisted and the chemical theory gained acceptance.

Some ten years later practical experience, fortified by early researches, led to the establishment of the sulphate-alkalinity ratio. This at the time appeared to provide the answer where relatively low pressures were involved, but with the advance in pressures the adequacy of this form of protection became open to question.

Meanwhile, intensive studies were undertaken at the University of Illinois Experiment Station and at the U. S. Bureau of Mines, dealing with contributing causes and the efficacy of various inhibitors.

Within the last two years there have been developed two forms of embrittlement detectors, one for laboratory use and the other for application to boilers in the field, by which it is hoped to determine whether the boiler water in use has embrittling characteristics and, if so, what inhibitors may be effective. Experience with such detectors in a large number of applications formed the subject of several papers at the Boiler Feedwater Sessions of the recent A.S.M.E. Annual Meeting, the results of which are summarized elsewhere in this issue.

Briefly, it appears from these experiences that certain organic materials will inhibit embrittlement in the majority of cases, although not under all conditions; that sodium nitrate has possibilities which warrant further study; that the sulphate-alkalinity ratio has rather indefinite limitations; and that embrittlement can be prevented by eliminating from the boiler water all alkalies that yield sodium hydroxide when the water is concentrated. Furthermore, the rather wide diversity in results emphasized that the field detector should be employed with care if misleading indications are to be avoided.

Fortunately, within recent years the widespread use of welded drum construction, in place of riveted drums, has largely removed the danger from embrittlement as concerns stationary boilers constructed within the last seven or eight years and operating at medium or high pressures. However, many older stationary boilers, locomotive boilers, tube ends and some fitting connections offer opportunities for intercrystalline cracking. The embrittlement detector appears to be a most useful, if not conclusive, tool for detecting the probability of such action to the end that remedial measures may be taken before damage and perhaps disastrous results take place. These investigations are to be continued and with each report of progress we appear to be nearer a definite solution of the problem.

Air Raid Protection for Power Plants

Fragmentary information has filtered through from time to time concerning damage to British power plants by bombing raids, although practically nothing has appeared in the foreign technical press. However, one large British power station is reported to have been put out of service some months ago and others are said to have been temporarily disabled.

It was most enlightening, therefore, to listen to the talk, at the recent A.S.M.E. Defense Luncheon, by W. D. Binger, Borough Engineer of Manhattan, who has lately returned from an inspection of British civil defense protection. Among other things, Mr. Binger cited one large British power station that had received twenty-two direct hits, despite which it was able to keep in operation. The method adopted for the protection of turbine-generators, is to encase them with two inches of cork over which is cast, in sections, removable reinforced-concrete slabs. While this does not afford protection against a direct hit on the unit, it provides adequate protection against flying debris from hits elsewhere in the station, as was demonstrated in some cases mentioned where the machines had kept running without interruption although station walls had been demolished. Mr. Binger pointed out further that damage to overhead transmission lines had been relatively light and easy to repair, in contrast to more serious damage with underground transmission. He did not state however, whether boiler plants had been damaged or what measures were being taken for their protection.

Now that the United States is definitely in the war it behooves us to profit to the utmost by experience abroad. Undoubtedly some further information has come through official channels and has been made available to the managements of some of our larger stations. If so, it would seem desirable to make it more generally available, for none can tell when and where such protection to our power stations may become necessary.

Topping Extension to WEST READING STATION

By GEORGE S. FRIES, Mech. Engr.
Atlantic Utility Service Corp.

This extension consists of a 22,000-kw high-pressure turbine-generator receiving steam at 1250 lb, 900 F, from two pulverized-coal-fired bent-tube boilers and exhausting into the 250-lb header of the old station, whose total capacity is thereby raised to 96,000 kw. The estimated net station heat rate has been lowered to approximately 12,500 Btu per kwhr.

TERRITORY served by the Metropolitan Edison Company, with headquarters in Reading, Pa., covers a large area in eastern Pennsylvania and a section of northern New Jersey, including such industrial centers as Easton, Reading, Middletown, Phillipsburg and Dover, with an average aggregate demand of approximately 225,000 kw. The principal steam-electric plants supplying the system are located at Holland, N. J., West Reading, Easton and Middletown. There is also a hydro plant at York Haven and tie-in connections are made with several adjacent systems.

The growth in system load, excepting dips in the curve during certain depression years, has been approximately 8 per cent annually, and decision was made in January 1937 to put into effect plans for additional capacity in the form of a high-pressure topping unit at the West Reading Station. The subsequent recurrence of depression during that year was responsible for deferring actual construction until January 1940, at which time it was also decided to add to the capacity of other stations on the system. In the interim certain advances in the design of steam generating units had been made, such as continuous furnace wall tubes, eliminating the intermediate headers, as well as improvements in the fly-ash precipitating system, and these changes necessitated redesigning some of the supporting steelwork at West Reading. This addition, consisting of two high-pressure pulverized-coal-fired boilers furnishing steam at 1250 lb, 900 F to a 22,000-kw topping turbine, went into service during October 1941.

The West Reading Station was built in 1910 and at that time contained sixteen 200-lb pressure boilers and two 4500-kw turbine-generators. In 1918–1920 two more boilers together with a 10,000-kw and a 20,000-kw turbine-generator were added, and in 1923 the capacity was further increased by the installation of six larger boilers furnishing steam at 250 lb to a 30,000-kw turbine-generator. Thus there were two operating pressures in the plant, 200 and 250 lb, the steam headers being connected through a reducing valve.

Subsequently, twelve of the original 200-lb boilers were removed and in 1937 the 20,000-kw machine was rebuilt for 25,000 kw at 250 lb pressure, making the station capacity at that time 74,000 kw.

Fig. 1—General view of station

When it was decided to increase further the capacity, studies were made of various arrangements and steam conditions. The plan finally adopted as providing the required capacity with the best economy under prevailing conditions was a topping installation of 22,000 kw at 1250 lb pressure and 900 F at the throttle, the turbine exhausting into the existing 250-lb steam header, with the 200-lb units held in reserve. The addition is housed in an extension to the building and it was found possible to utilize one of the existing stacks for the high-pressure boilers, thus not disturbing the architectural features of the station by the addition of a fifth stack. By means of a 90-deg crosstie the bunkers of the extension were supplied by the existing coal-handling system which had ample capacity in view of the lower coal rate indicated. Calculations showed that by topping, the overall station coal rate would be reduced from 1.66 lb to well under 1 lb per kwhr and the net station heat rate to approximately 12,500 Btu per kwhr.

Turbine-Generator

The high-pressure turbine-generator is of Westinghouse design, employing both impulse and reaction stages, and runs at 3600 rpm. The generator is air cooled and the exciter direct-connected. Taking throttle steam at 1250 lb, 900 F, the back pressure is 265 lb and the exhaust is sufficient to take care of the 30,000-kw low-pressure machine as well as 14,100 kw of the 25,000-kw machine, the remaining steam for this unit being supplied by the 250-lb boilers.

Desuperheating, pressure-reducing equipment and a quick-opening stop-valve are provided so that if electrical load is lost on the topping unit, high-pressure steam is bypassed, within two seconds or less, through the desuperheater to the low-pressure header of the old

plant. Important in this respect is a Bailey flow-control device which maintains the setting of the reducing valve in accordance with the rate of steam flow through the turbine.

All the low-pressure boilers are stoker fired but it was decided to employ pulverized-coal firing for the new steam generating units. The proposed coal upon which the design was based was eastern Pennsylvania bituminous of 13,839 Btu average heating value, 17.43 per cent volatile, 8.65 per cent ash, 2700 F ash-fusing temperature and 80 grindability (Hardgrove). It was also anticipated that the load would primarily be variable. These considerations dictated the selection of a dry-bottom type of furnace. However, because of favorable price differentials in this locality, which is the load center of the system, several different coals are actually being burned and it becomes desirable to operate at a high load factor.

Steam-Generating Units

The two new steam-generating units are of the Combustion Engineering three-drum bent-tube type, each with fin-tube economizer, Ljungstrom air preheater and bubble-type steam washer. The furnaces are completely water-cooled (including the hopper-shaped bottoms), with fin tubes and opposed firing is employed; that is, there are two turbulent-type burners in the front wall opposite two in the rear wall. It was felt that the opposed firing would make for reduced carbon losses in fly ash, increased stability in operation and a reduction in slagging difficulties—all of which appear to be borne out by operation to date. Superheat control is effected by means of bypass dampers. Following are data applying to each of the boilers:

Capacity (max. continuous)	275,000 lb per hr
Design pressure	1400 lb per sq in.
Operating pressure	1265 lb per sq in. (superheater outlet)
Steam temperature	900 F
Heating surface	
Furnace walls	5179 sq ft
Boiler	5488 sq ft
Superheater	6400 sq ft
Economizer	8420 sq ft
Air preheater	20,200 sq ft
Furnace volume (gross)	17,000 cu ft
Overall efficiency expected at maximum rating	87.5 per cent

Each steam generating unit has two forced-draft and two induced-draft fans of the Sturtevant vane-control type, driven by constant-speed motors. The former are of 55,000 cfm each and driven by 100-hp motors while the latter are of 93,000 cfm and driven by 300-hp motors. The forced-draft fans are totally enclosed and take air from the outside. The breechings are Gunited on the inside to guard against corrosion.

An air-operated Bailey system of combustion control is employed.

Two C-E Raymond bowl mills supply the burners of each unit. Their size is such that one mill will handle up to 60 per cent boiler capacity. Furthermore, by pro-

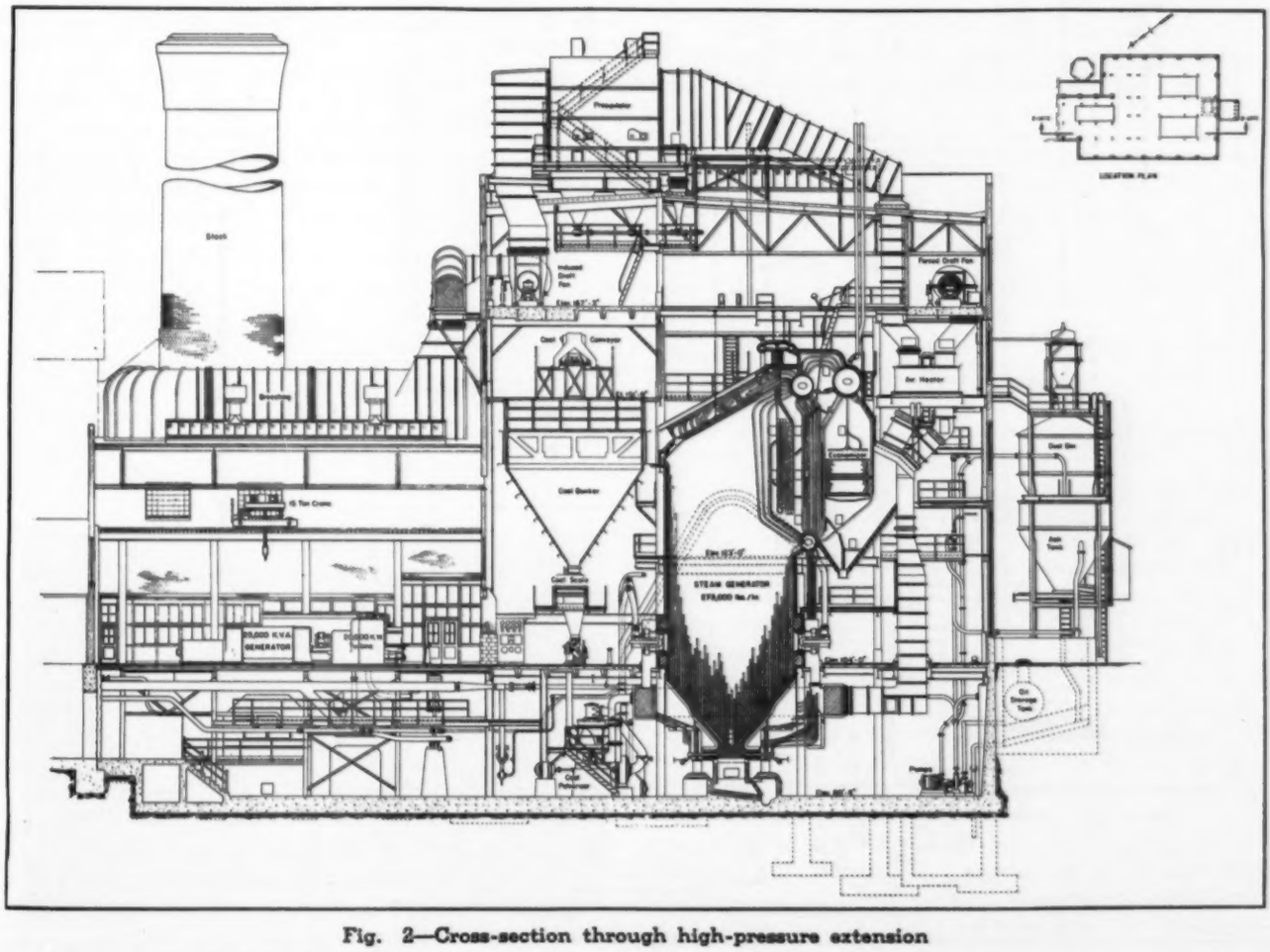


Fig. 2—Cross-section through high-pressure extension

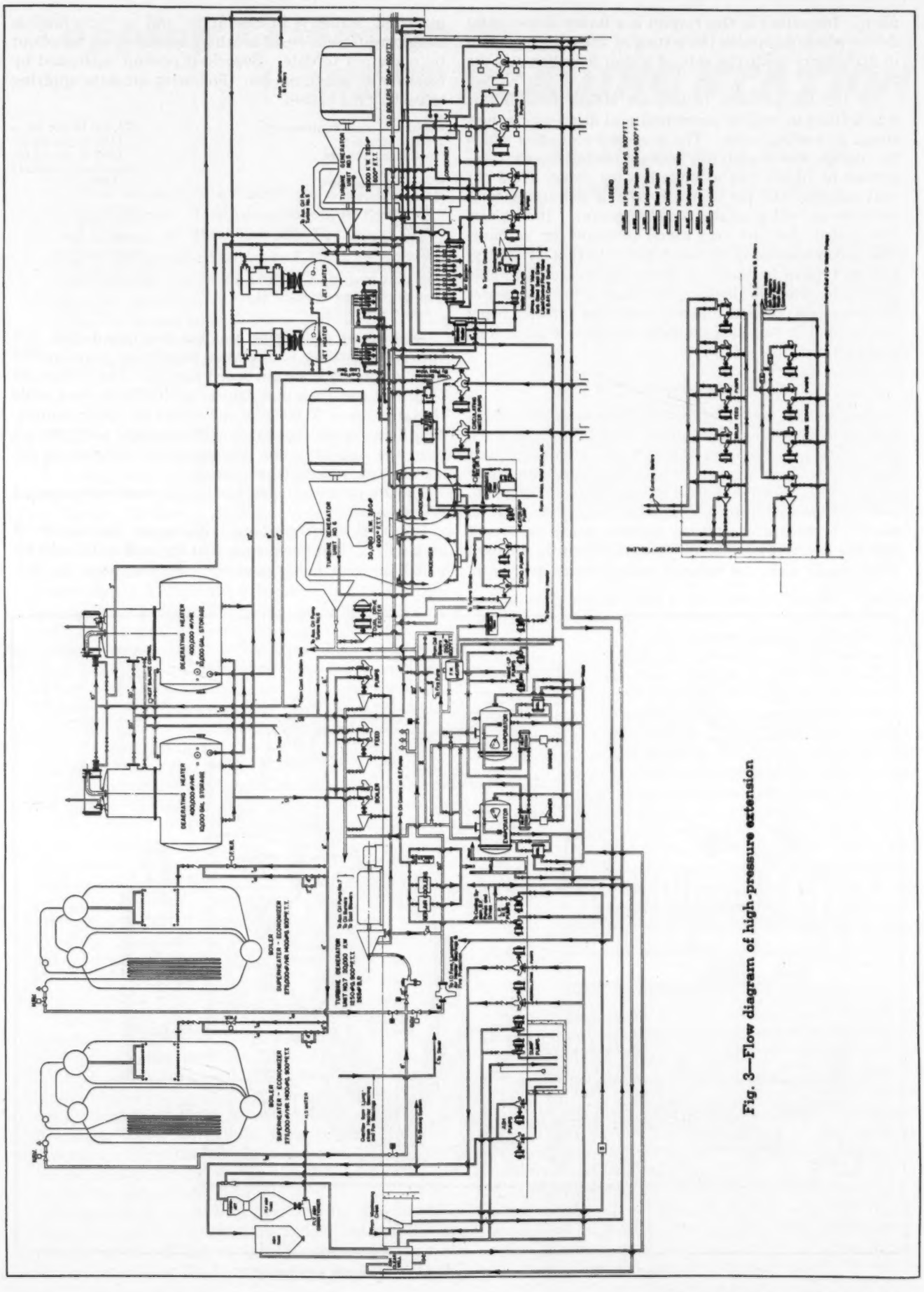


Fig. 3—Flow diagram of high-pressure extension

viding duplicate auxiliaries for each steam generating unit maximum flexibility is attained.

An idea of the general arrangement of the equipment can be had by reference to the cross-section in Fig. 2.

Fly ash is arrested by electrostatic precipitation of the Research Corporation type and ash from the furnace bottoms is handled by an Allen-Sherman-Hoff Hydrojet system, whereas a Hydrovec system handles the fly ash from the economizers and the precipitators. This fine ash is hauled away wet in trucks and used for fill at the rate of about 30 tons per day. The water employed with the ash-conveying system, being in a closed circuit, is used over and over again; hence there is no contamination of the river.

Feedwater System

Makeup water is taken from the Schuylkill River and Wyommissing Creek, the two supplies being blended to give a natural sulphate ratio. The raw water is treated with alum and passed through a Zeo-Karb system, then goes to a deaerating heater which raises its temperature to 214 F ahead of the booster pumps from which it passes to double-effect evaporators. Distilled water from the evaporators goes direct to deaerating heaters. Reference to the flow diagram, Fig. 3, shows clearly the path of the feedwater. Each of the three high-pressure boiler feed pumps of Ingersoll-Rand design, is rated at 680 gpm with feedwater at 214 F, and is driven by an 880-hp, 5-stage Elliott turbine, taking steam at 250 lb and exhausting at 3 lb back pressure. The variable speed permits saving of steam and assures closer feedwater control.

There is a Copes two-element air-operated feedwater regulator on each boiler with air-operated control for the hydraulic governors on the turbines driving the boiler feed pumps. The blowoff valves are of the Yarnall-Waring type with welded connections, the gage glasses of Reliance design and the safety valves of the Crosby type.

Steam Piping

All the high-pressure steam piping, as well as the boiler-feed piping and part of the low-pressure piping, are welded and the high-pressure steam piping is carbon-molybdenum steel. Also all valves and fittings are welded, no flange connections being used except for the safety valves. The Westport type of joint and the A.S.M.E. Standard with chill ring were employed. During the welding operation the pipe temperature was held at 400 F and when completed the welds were stress-relieved at 1200 F by means of induction heating coils. Under a subsequent 2400-lb hydrostatic test no leaks whatever developed.

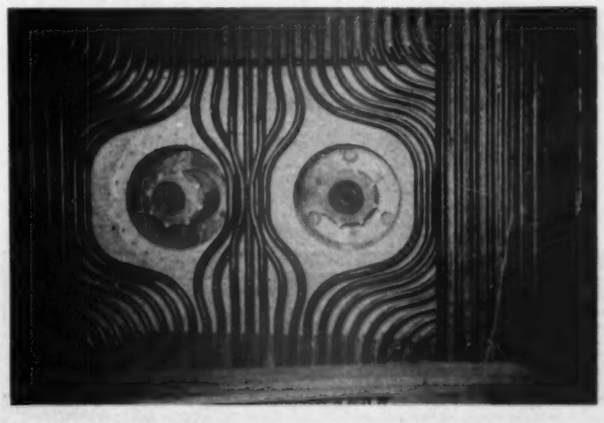


Fig. 4—Front wall burners as viewed from furnace

Fig. 5—Ash-discharge chamber looking up through furnace bottom

The extension was designed by the Utility Management Corporation (now the Atlantic Utility Service Corporation) of Reading, Pa., consulting engineers for the Metropolitan Edison Company.

Production of Electricity and Fuel Consumed by Utilities in October

According to a Federal Power Commission report, dated November 21, the production of electric energy for public use during October 1941 totaled 14,991,953,000 kwhr which represents an increase of 17 per cent compared with October 1940. The total production for the twelve-month period through October was 161,045,000,000 kwhr which represented an increase of 15.1 per cent over this period for last year. The capacity of electric generating plants in service as of October 31 was 43,412,706 kw, which figure shows a net increase of 455,670 kw over that previously reported.

The production by water power in October amounted to 27.9 per cent of the total output for public use. This figure is lower than normal due to a marked decrease in the South Atlantic and East South Central regions as a result of the long prevailing drought in those sections of the country.

The coal consumption for October 1941 was 6,218,064 tons which was an increase of 400,757 tons over that of September. Of this total 5,944,991 tons was bituminous coal and 273,073 tons anthracite, representing increases of 7.1 per cent and 3 per cent, respectively, over the figures for the preceding months which had one less day. The fuel oil consumption of 1,816,956 bbl for October was an increase of 9.8 per cent over that of September, but the consumpton of natural gas decreased 6 per cent.

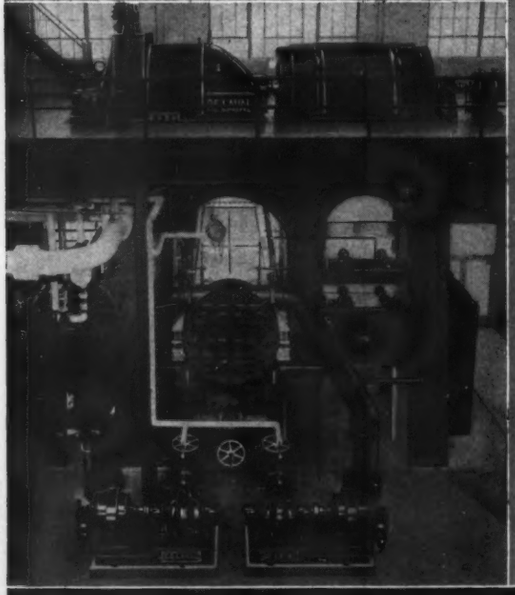
Total coal stocks on hand at electric utility power plants on November 1, 1941 aggregated 13,290,566 tons, or an increase of 2.6 per cent as compared with October 1 of this year and an increase of 6.2 per cent over the figure for November 1, 1940.

Efficient TURBO-ALTERNATORS

De Laval multistage impulse turbines specially designed for high economy with modern steam conditions and direct-coupled to alternators are now available in all capacities from 500 to 15,000 kw.

De Laval multistage turbine driving 4000 kw. (5000 kw. maximum) Crocker-Wheeler 60 cycle alternator in Wyandotte, Mich. Municipal power plant. The turbine receives steam at 425 psi. and 720° F. and exhausts to condenser. It is also arranged for bleeding at the 6th, 11th and 15th stages. A similar unit rated at 6000 kw. has since been ordered.

▼ Condenser installation, showing duplicate motor-driven De Laval circulating pumps.



WHEELS and shafts are of nickel steel, buckets and vanes of stainless steel and monel, and casings of cast molybdenum and carbon steels and molybdenum cast iron, according to steam temperatures.

Separation of water in the low pressure stages materially improves economy and reduces blade erosion.

Governing of admission valves is by two stages of hydraulic amplification from a sensitive and accurate fly-weight governor, with manual or remote synchronizing control. A separate throttle trip valve is operated by emergency stopping mechanism independently of the speed control.

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Experience with Embrittlement Detector

A group of papers at the Feedwater Session of the A.S.M.E. Annual Meeting dealt with a large number of field tests of boiler water with the Schroeder embrittlement detector as well as with laboratory tests employing the detector devised by Straub and Bradbury. By these means the effects of various embrittlement inhibitors were studied. The results appeared to confirm the growing belief that the prescribed A.S.M.E. sodium sulphate-total alkalinity ratio is no definite insurance against embrittlement particularly in the higher pressure ranges. In some of the investigations reported, sodium nitrate appeared to be an effective inhibitor.

A PAPER by **E. P. Partridge, C. E. Kaufman** and **R. E. Hall** (all of Hall Laboratories, Inc.) reported progress based on test data from 100 embrittlement detectors of the Schroeder type installed on boilers in actual service. This detector,[1] as shown in Fig. 1, consists of a specimen of boiler steel placed between a clamping block and a vessel containing boiler water. A small hole is drilled through the wall of the latter for contact of the boiler water with the specimen. By means of an adjusting screw the specimen is stressed and a space formed just sufficient for a small amount of leakage and the building up of a concentrated solution. The screw is ordinarily adjusted so that only a very small amount of vapor escapes—just sufficient to be detected as a slight haze on a cold glass or polished metal. Too great an opening will defeat the purpose by permitting the concentrated solution to be washed out. Cracking of the specimen indicates that the boiler water may be capable of promoting intercrystalline cracking in a riveted seam and should serve as a warning that corrective treatment should be initiated.

This field work covered a period of approximately two years and led to the following conclusions:

1. Neither sulphate nor chloride, nor sulphate and chloride in combination show evidence of an inhibiting effect over the range of pressures above 250 lb per sq in. At pressures up to this some effect is indicated by the limited data of the authors, but is contradicted by the published results of some other detector tests.

2. R_2O_3 (alumina) has not proved effective as an inhibitor of cracking either in the suggested range above 500 lb per sq in. or at lower pressures.

3. Phosphate appears to be without effect as an inhibitor, even at a $PO_4/NaOH$ ratio as high as 2. This does not deny, however, the possible utility of eliminating sodium hydroxide substantially from a boiler water containing phosphate by controlling the pH in the range below 11.

4. The experience of the authors with nitrate is not yet sufficiently extended to justify any conclusions concerning its effect.

5. Tannin, as determined by the tyrosin test, seems effective as an inhibitor over the range up to 650 lb per sq in. in which it has been used to date.

In view of these results the authors point out that it would not seem logical to accept with blind faith the semiofficial sulphate-alkalinity ratios, nor with blind zeal to replace them with some other system of ratios based upon the effect of tannin or any other proposed inhibitor. Instead, it is suggested that full advantage be taken of the testing methods now available, and that each operator determine, with the assistance of whatever coordinating agency he may choose, the conditions which he can most effectively and economically maintain in his own boilers to minimize the likelihood of cracking.

If there are no boilers with riveted seams, the operator may feel justified in ignoring the problem, although he may still wish to take precautions to avoid the admittedly rare possibility of intercrystalline cracking in tube ends. Along with the operator directly concerned with riveted construction, he can, by means of the embrittlement detector, first test his boiler water under existing conditions. If specimens crack in repeated tests, he can then explore the effect of changes in feedwater treatment and will be likely to find conditions under which the steel of the detector specimen will remain uncracked.

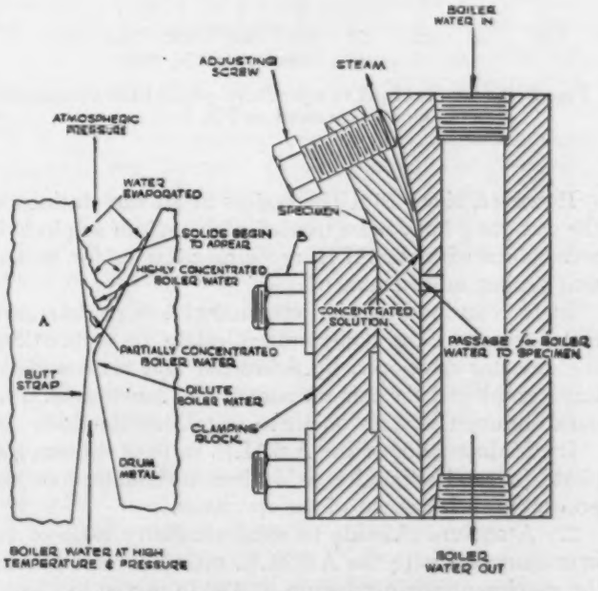


Fig. 1—Sketch of Schroeder embrittlement detector

[1] For full description see COMBUSTION, August 1940, p. 19.

T. E. Purcell and **S. H. Whirl** reported on the results of 26 tests with the Schroeder embrittlement detector on boilers operating under varying conditions at plants of the Duquesne Light Company.

Early experience with intercrystalline cracking in the riveted drums of twenty-six Stirling boilers installed between 1914 and 1919 at the Brunot Island Station were cited. In these the A.S.M.E. sodium sulphate-alkalinity ratio had not been maintained and examination had shown evidence of misalignment of rivets and poorly fitted butt straps.

No failures from embrittlement were experienced at the Colfax Station, built in stages between 1920 and 1927, although much trouble was had from corrosion and scale until caustic soda and oxygen scavengers were employed.

At the James H. Reed Station, built in 1930, makeup is provided by evaporation of zeolite-softened Ohio River water, and neither scaling nor corrosion has been encountered.

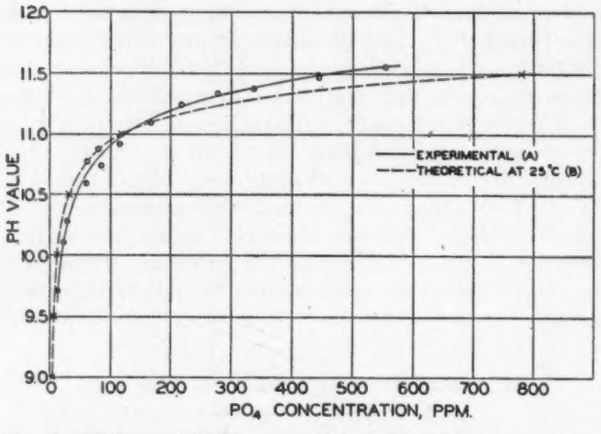


Fig. 2—Relation of pH to trisodium-phosphate concentrations expressed as PO_4 Ion

However, since 1931 the boilers of all the stations of the company have been treated with sodium sulphate in accordance with A.S.M.E. recommendations for protection against embrittlement.

In 1938 an investigation was undertaken to determine to what extent the boiler waters might be embrittling, the detector developed by Schroeder and his associates being employed for this purpose. The conclusions from data obtained to date on these tests indicate that:

1. Maintenance of the A.S.M.E. ratio of sodium sulphate to total alkalinity as sodium carbonate does not prevent embrittlement of the specimen.
2. A sodium chloride to total alkalinity ratio of 1.6 in conjunction with the A.S.M.E. ratio does not protect the specimens against failure at 420 lb per sq in.
3. Specimen cracking is not encountered in boiler waters in which the alkalinity is controlled on the basis of a pH value corresponding to the phosphate concentration as shown in Fig. 2.
4. Sodium nitrate appears to offer possibilities as an inhibitor against embrittlement.
5. Under some conditions the duration of the test period is an important item.

The authors observed that while the Schroeder detector simulates conditions in a leaking boiler seam, it undoubtedly accelerates the action, for experience has shown that boilers which leak may operate for a long time without failure. Since caustic soda is the active chemical there are two logical methods of affording protection against its action. One is to control the alkalinity with chemicals which upon evaporation do not deposit caustic soda, and the other is to employ inhibitors. The tests covered both methods, the use of trisodium phosphate being an example of the first and the presence of nitrates in the boiler water illustrating the second.

Due to variable feedwater quality in some stations, use of trisodium phosphate alone may not be feasible. An acid feedwater would require excessive amounts of this chemical and result in high boiler-water salines, whereas an alkaline feedwater would tend to defeat the purpose of the treatment by developing caustic alkalinity. Furthermore, oxygen scavengers may be necessary in some cases.

However, it is possible to adhere to the principle of this method of treatment by controlling the pH of the boiler water with requisite amounts of either alkaline or acid chemicals, the relation of pH and trisodium-phosphate concentration in pure water being as shown in Fig. 2. As long as the pH and phosphate concentration conform to this curve, trisodium-phosphate salt will be obtained on evaporation and no caustic soda will be present. The optimum condition, with respect to embrittlement, corrosion protection and boiler-water salines is the maintenance of the pH value slightly below that on the curve corresponding to the desired phosphate concentration.

A third paper dealing with a series of tests employing the Schroeder embrittlement detector was offered by **P. G. Bird** and **E. G. Johnson,** both of National Aluminate Corporation. These tests were conducted in the laboratory and two types of waters were employed—one consisting of synthetic solutions and the other boiler waters, to which in many cases had been added inhibitors. These inhibitors included lignin compounds, sodium nitrate and various tannins. In all cases a pressure of 200 lb per sq in. was maintained and the boiler waters had a hardness of 120 ppm as $CaCO_3$, alkalinity of 166 ppm, sulphates as Na_2SO_4 of 132 ppm, NaCl of 43 ppm and SiO_2 of 45 ppm. Steels of various composition were also investigated. Tables showing results with each were included.

The tests with boiler water showed that, in general, as the concentrations increase, a greater amount of organic matter is required for complete protection. There was no indication that inorganic salts ordinarily found in boiler waters exert a pronounced protective action; this is also true of sodium sulphate. While some tests indicated that a high sulphate content may interfere with the protective action of organic substances, this effect was not pronounced or consistent enough to serve as a basis for concluding that sulphates are harmful. Of the inorganic substances tried, sodium nitrate appeared to be one of the best. It is not nearly as effective alone as when combined with organic matter. Because of this, some organic substances were nitrated and tested but these nitrated materials were in general not effective.

The authors cautioned that because of the careful adjustment required in the use of the detector, it should

be used only in the hands of skilled operators; otherwise, the results might be misleading.

Experience with Locomotive Boilers

In view of vast number of steam boilers in locomotives which operate under widely diversified conditions and with waters of many compositions, the experience of The Chesapeake & Ohio Railway with intercrystalline cracking is most pertinent. This was told in a paper by **R. C. Bardwell** and **H. M. Laudemann,** which reviewed investigations with various inhibitors covering a period from 1933 to the present and during the last two years of which the Schroeder embrittlement detector was available.

Through and east of the Allegheny Mountains, the waters contain but little sulphate and the ratio of sodium sulphate to total alkalinity in the boilers rarely exceeded 1 to 1. On the other hand, in the Ohio River district and through Ohio and Indiana, the sulphates are much higher. Out of 203 cases of intercrystalline cracking reported, 66 per cent were in the territory of the high sulphate ratios and 34 per cent in the territory of low ratio; which would indicate that if this salt had any value in preventing embrittlement, the reverse of this situation should have existed.

As a result of investigations reported by the U. S. Bureau of Mines, the railroad began the use of waste sulphite liquor (containing large amounts of lignin) as an inhibitor in 1938, and the following year the embrittlement detector became available and this was subsequently applied to fifteen switching locomotives operating in widely scattered areas.

These tests indicated[1] that waste sulphite liquor is satisfactory for many waters, but its protective action can fail in some cases. Despite this, its use brought about a marked reduction in the number of cases of intercrystalline cracking reported during the two years it was in use.

During the latter part of 1940, the West Virginia Pulp and Paper Company, from which the waste sulphite liquor had been obtained, changed its manufacturing process and the supply from this source was no longer available. Acting upon the reports of later investigations by the Bureau of Mines, the railroad then turned to the use of sodium nitrate to prevent embrittlement. This was claimed to be less subject to interference from the presence of other substances in boiler water than was the case with sulphite liquor.

After the nitrate treatment had been in use about three months at two locations where cracking had been prevalent, a thorough inspection was made of the engine boilers and they were found to be in excellent condition. The treatment was then introduced on the entire system. Furthermore, it has eliminated cracking of the detector specimens. The tests are being continued with different amounts of nitrate concentration.

Laboratory Detector Test

F. G. Straub reported the results of 1300 laboratory embrittlement tests of boiler waters as a part of an investigation conducted under a cooperative agreement between the Utilities Research Commission, Inc., Chicago, and the University of Illinois Engineering Experiment Station. In these tests the laboratory type of embrittlement detector previously described by Straub and Bradbury was employed.[2]

[1] See *Mechanical Engineering*, Vol. 60, 1938, pp. 371–376, and COMBUSTION, August 1938, p. 29.

The results of tests conducted at 400 F indicate that with low sodium chloride content, sulphates do not appear to be effective in preventing failure of the test specimens. When the sodium chloride exceeds about 0.6 of the alkalinity or 1.0 of the sodium hydroxide content, the combination of sulphate and chloride appears to be effective in preventing failure. In many waters having low chloride content and which produced failure in the laboratory tests, chlorides have been added with the result that failure has been prevented.

At higher temperatures of 470 F and 570 F there appeared to be a definite influence exerted by the R_2O_3 content in respect to that of the SiO_2. It has been noted that when the chlorides are rather low, the failure occurs even when the R_2O_3 content is comparatively high. However, when the chloride is increased, the failures are prevented.

During the tests the stress on the specimens was held to around 40,000 lb per sq in. for a steel of about 36,000 lb per sq in. yield strength. Such stress might be encountered as localized around rivets, etc. But it was found that if the stress is increased to around 50,000 to 55,000 lb per sq in., no reasonable combination of salts, either inorganic or organic, would prevent failure. The author cautioned, however, that the results are those represented by laboratory tests and are not those of actual cracking in power plant boilers.

Conclusions

Summarizing the results as brought out in these papers, **W. C. Schroeder** and **A. A. Berk** of the U. S. Bureau of Mines expressed the following conclusions:

1. Certain tannins, especially those of the quebracho type, will retard embrittlement cracking in test specimens. Relatively low concentrations are sufficient even at the higher pressures. The protective action probably decreases around 500 lb per sq in., although the tannin has been successfully used in one case at 650 lb.

2. Lignins will prevent cracking of test specimens in many boiler waters. In some instances, however, they are not satisfactory. One investigation has indicated that their protective action may be increased by the use of a small amount of sodium nitrate. This possibility needs further study.

3. The data in the symposium do not show that sodium sulphate will prevent embrittlement cracking in test specimens.

4. The data are in agreement that sodium sulphate and sodium chloride do not prevent cracking at pressures above 250 lb. At lower pressures the various authors are not in agreement concerning the action of these salts.

5. A boiler water containing sodium hydroxide in appreciable concentration cannot be treated with sodium phosphate to prevent cracking in specimens.

6. Embrittlement can be prevented by eliminating from the boiler water all alkalies which will yield sodium hydroxide when the water is concentrated. The pH in the boiler water is then maintained by the use of sodium phosphate. This method of treatment is intended for boilers using evaporated makeup.

7. Sodium nitrate appears to inhibit embrittlement in the detector tests at least up to around 300 lb per sq in. pressure.

ENGINEERS INSPECT MONTAUP BOILER

ON December 5, following the A.S.M.E. Annual Meeting, a party of more than 150 engineers, as guests of J. V. Santry, President of Combustion Engineering Company, left New York by special train to inspect the large C-E controlled forced-circulation boiler now nearing completion at the Somerset Station of the Montaup Electric Company.

This unit, of 650,000 lb per hr maximum continuous capacity at 1825-lb pressure and 960 F steam temperature at the superheater outlet, represents the first large-scale commercial application of forced circulation in this country, although more than nine hundred such installations of much smaller capacity are in service abroad.

Fundamentally, the essential difference between this unit and a conventional boiler is that the hydraulic head normally available for natural circulation is augmented by circulating pumps, operating under a differential pressure of about 50 lb between the downcomer from the upper drum and the headers at the bottom of the furnace. Furthermore, distribution of water to the various circuits is controlled by means of orifices inserted at the entrances to the individual tubes where they connect to the lower header system. The quantity of water handled by the circulating pumps is substantially in excess of the steam production and this insures wetted surfaces at all points where gas contacts the tubes. Circulation is independent of the load.

In contrast with the conventional unit having convection boiler heating surface, the heat transfer, except in the second superheater stage, the reheater and the economizer, is all by radiation; and the employment of small diameter tubes, of $1^1/_4$-in. diameter, assures a high degree of turbulence under the high velocities employed. This is especially important in avoiding deposits on the tubes.

Forced circulation also permits flexibility in the arrangement of heating surfaces and steam drum to meet space requirements, for the elevation of the drum is not determined by the hydraulic head, as is required to assure circulation in the case of a natural-circulation boiler, particularly where high pressures are involved.

The Montaup unit will be tangentially fired with pulverized coal from the existing storage system in the plant, with provision for oil firing as an alternate fuel. There are twenty-four burners in all—three pulverized-coal burners and two oil burners in each corner and four auxiliary burners. The furnace is completely water cooled with $1^1/_4$-in. O.D. bifurcated tubes and the bottom is of the continuous slag-discharge type.

The superheater is of the two-stage Elesco type with temperature control by means of bypass dampers; and a reheater of the gas-swept type, located between the two superheater stages, reheats the steam at 372 lb from the 25,000-kw high-pressure turbine to 765 F. Beyond the reheater is an Elesco fin-tube economizer and beyond that two Ljungstrom air preheaters. Feedwater will enter the economizer at approximately 440 F. A Hagan system of combustion control will be employed. It is significant that this boiler occupies a space originally laid out for one-third the capacity.

There are three eight-stage turbine-driven boiler feed pumps of Ingersoll-Rand design, each of 425,000 lb per hr capacity. Ordinarily two pumps will be in operation, but if necessary one can be speeded up to supply almost the full load requirements of the boiler. The circulating pumps, of which there are three, operating under 50 lb differential head, are also of Ingersoll-Rand design, each rated at 1,400,000 lb of water per hour. Two of these pumps have dual turbine (Terry) and motor drive and the third is motor-driven.

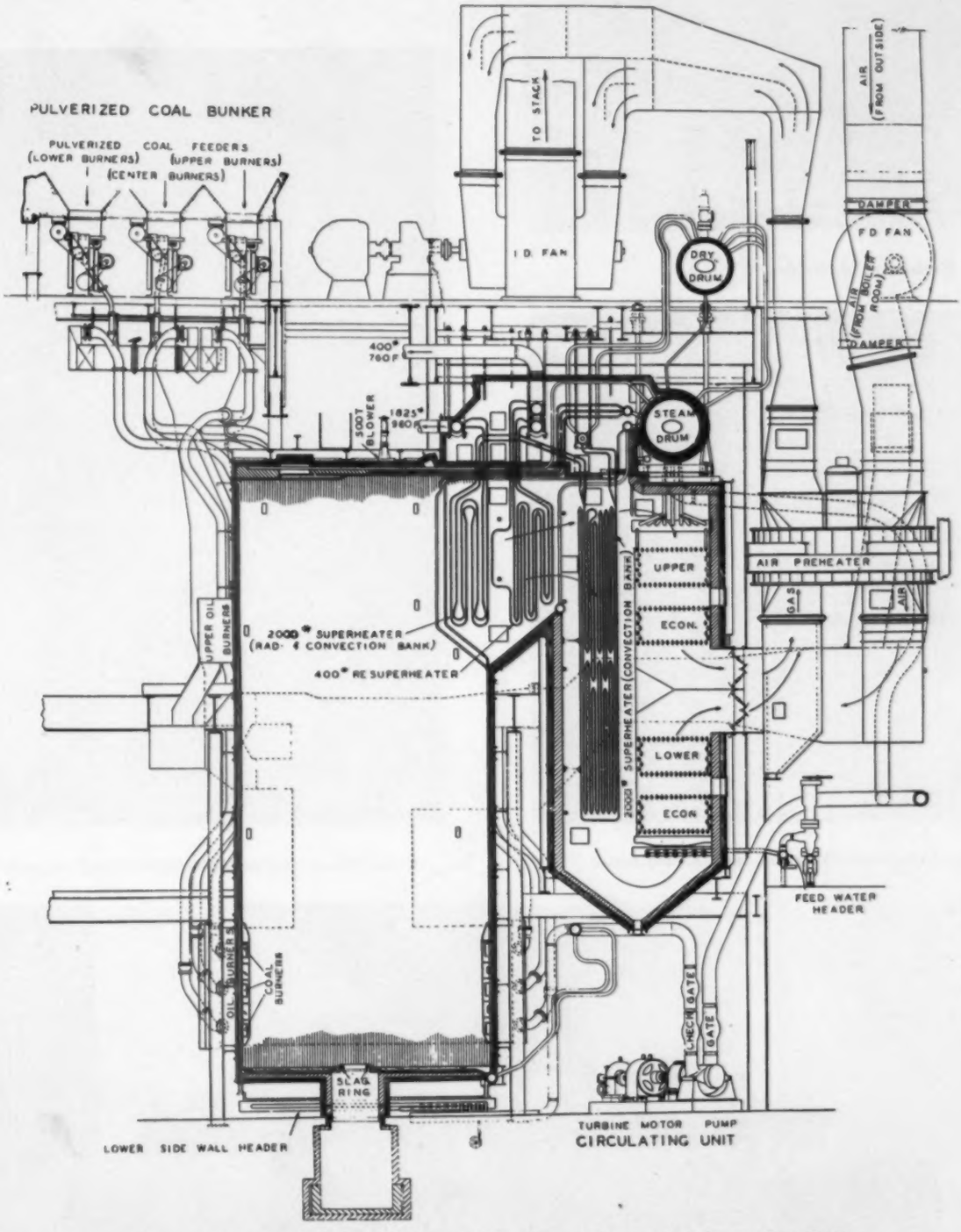
As indicated by the accompanying illustrations, the design of this boiler involved many unusual features of construction and erection, particularly because of the vast amount of small tubing and the number of field welds necessary, no rolled joints being employed in the high-pressure parts. Following are some pertinent data:

MAIN STEAM DRUM	
Length	43 ft
Inside diameter	54 in.
Plate thickness	$4^{33}/_{32}$ in.
Weight, with attachments	72 tons
FURNACE (completely water cooled and continuous slagging bottom)	
Width	32 ft
Depth	20 ft 9 in.
Height	48 ft
Volume	31,000 cu ft
Size of tubes	$1^1/_4$ in. dia.
All tubes bifurcated and connections to drums and headers welded	
LENGTHS OF TUBING	
Furnace	11.9 miles
Economizer	2.3 "
Superheater	7.1 "
Misc.	1 "
Total	22.3 "
Number of field welds (exclusive of fittings)	2640
Water in circulating system (exclusive of economizer)	7800 gal
Capacity of circulating pumps	3500 gpm
Head on circulating pumps (differential)	50 lb
Time for complete circulation of water in system (2 pumps operating)	about 1 min
Power input to circulating pumps in relation to full load plant output	0.30 per cent

An interesting comparison of weights between the use of $1^1/_4$-in. tubes and what would have been required for the same furnace with 3-in. tubes follows:

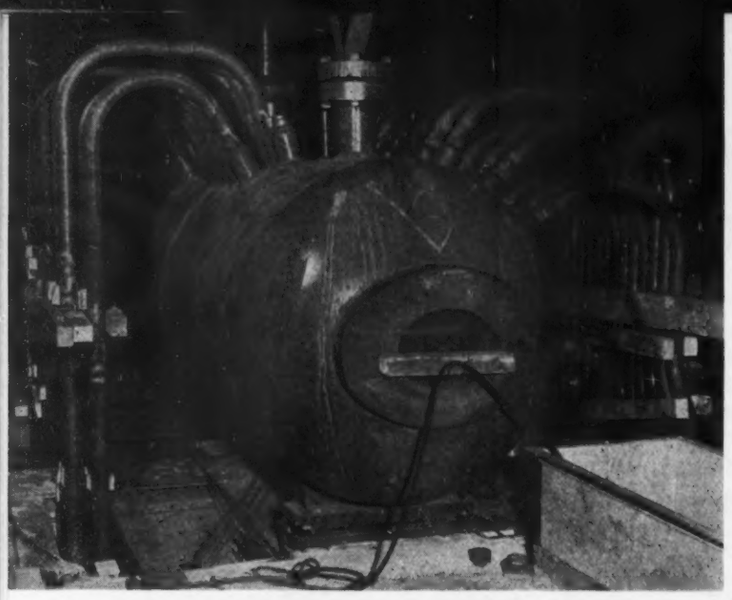
	Forced Circulation $1^1/_4$ In. Bifurcated	Natural Circulation 3-In. Bifurcated	3-In. Pinned
Weight of pressure parts (exclusive of superheater and economizer)	1	1.36	1.17
Weight of furnace tubes only	1	2.10	1.56
Water in furnace tubes only	1	2.74	1.77
Water in circulation (exclusive of that in economizer)	1	1.53	1.26
Thermal capacity of water and metal (exclusive of superheater and economizer)	1	1.46	1.23

At present there are in the station five 400-lb. boilers supplying 75,000 kw-turbine capacity. The new boiler will serve a 25,000-kw topping turbine exhausting to 47,800 kw of low-pressure turbine capacity, thus making 72,800 kw supplied by the high-pressure boiler. The remaining 27,200 kw of low-pressure turbine capacity will be supplied by two of the present 400-lb. boilers and the remaining three will be held in reserve.



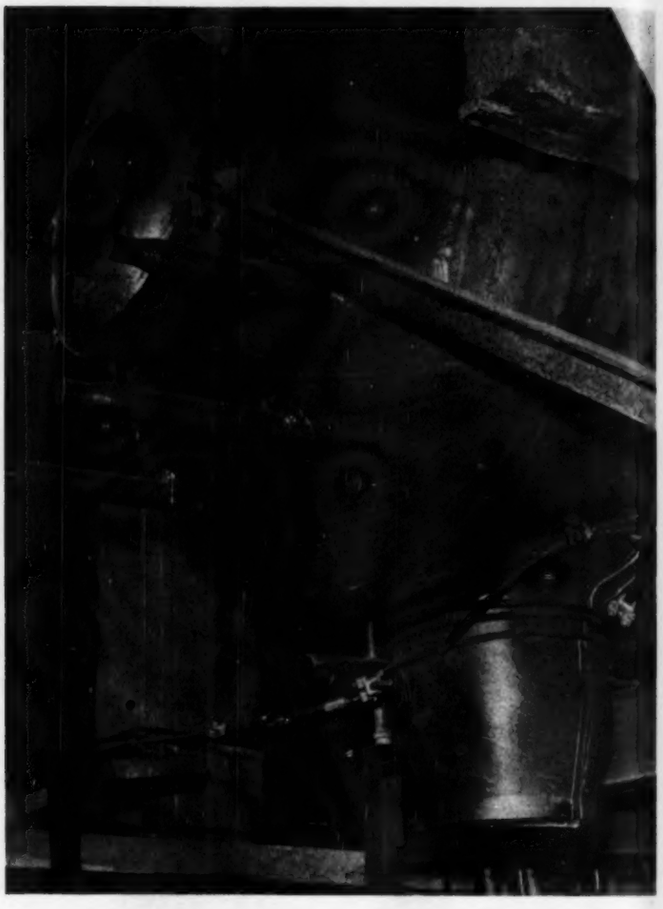
Cross-section through Forced Circulation Unit with essential parts identified

Construction Views Forced - Circulation

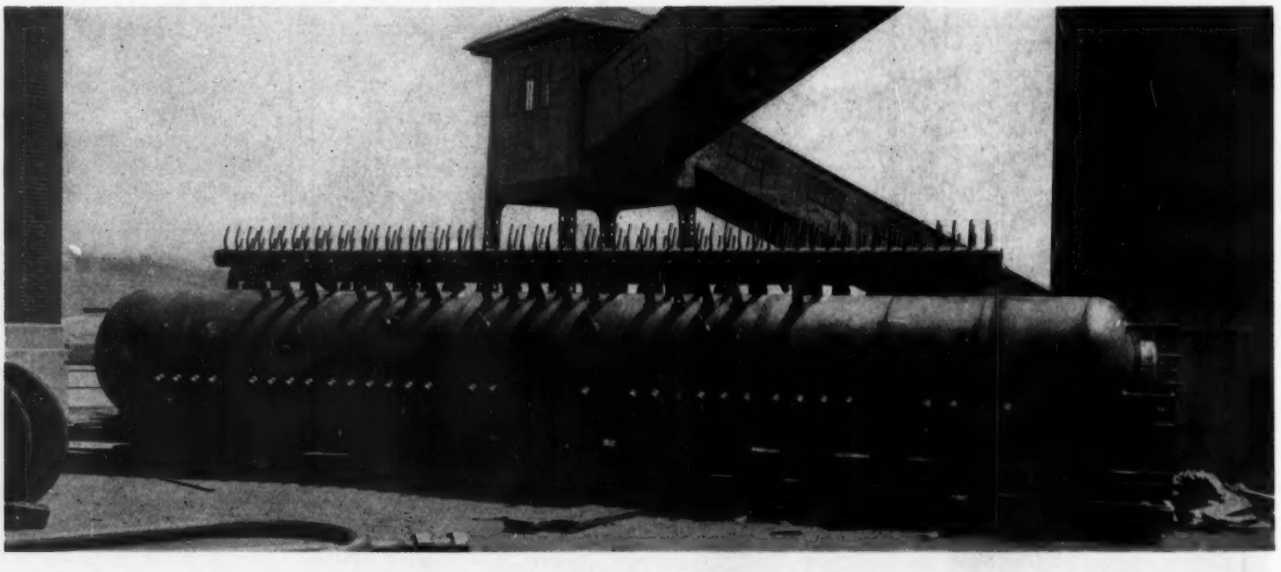


Right end of dry drum

Welding lower ends of rear circulators to main steam drum



Right end of main steam drum showing downtake nozzle

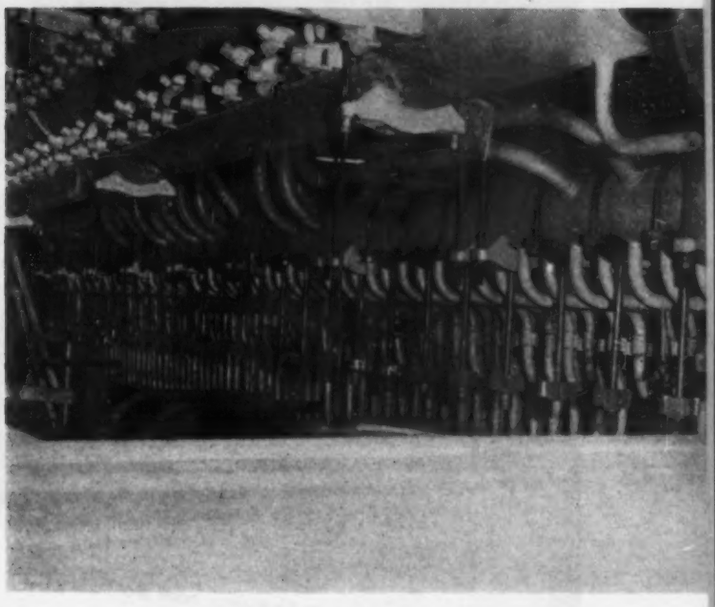


View of main steam drum on skids at plant

of C-E Controlled Boiler at Somerset

Corner view in furnace showing tangential burner

Rear circulators at dry drum



Reheater headers (top left) and first stage superheater header

Upper left rear corner of furnace showing roof, left side wall and front bank of boiler tubes

Why did **SIX** tubes crack . . . and no more?

ANOTHER UNUSUAL STORY OF HALL SERVICE

TIME: Early this year.

PLACE: Hall-client boiler plant.

TROUBLE: Four-drum, bent-tube-type boiler being returned to service after ten-year shutdown—six tubes in No. 5 row between back top and bottom drums found severely cracked transversely at upper-end tube seats. Boiler inspector and plant superintendent feared cracking was of embrittlement type. Familiar with embrittlement detectors through discussions issued by Hall Laboratories, superintendent ordered a detector to find out if water had embrittling characteristics.

HALL ANALYSIS: Trouble-shooting Hall service man inspected boiler and cracked tubes—searched particularly for special conditions of possible significance. Only six tubes in No. 5 row were cracked, distributed evenly across the row, *not* confined to any one section. Gas baffle between middle and back drums was supported partly on special tubes—No. 22 row—partly by clamps around six tubes in No. 5 row. Cracked tubes all failed in same relative location—circumferentially within the seat—in each case on tube fronts. *The six tubes that cracked had been those which supported the baffle!*

SOLUTION: When baffle was first installed, supporting clamps were so attached that expansion imposed excessive stress on tubes at their upper seats. Now, with baffle attached to six new tubes in a way that prevents excessive stress, no more trouble has occurred. Nevertheless, use of embrittlement detector will prove whether or not water is embrittling in character—a particularly interesting case because there is plenty of sulphate in the water to maintain the constant ratio of sulphate to alkalinity recommended by the A.S.M.E. code for protection from embrittlement.

What Hall Service can do for you

Hall Service means far more than just water conditioning. Hall Engineers help you keep your plant *in operation*, whether the problem is one of scale, corrosion or embrittlement in your boiler, or any of several other difficulties encountered both inside and outside your power plant.

This kind of service is particularly important in times like the present, when new equipment is difficult, if not impossible, to secure. Call in a Hall Service Engineer for a thorough check-up of your boilers. You will be infinitely better equipped to prevent troubles before they cripple your plant—at a time when you have *got* to make the *most* of what you *have*.

HALL LABORATORIES, INC. · 300 ROSS STREET · PITTSBURGH, PA.

HALL SYSTEM *of Boiler Water Conditioning*

Marine Power Plant Employs 1200 Lb Steam Pressure

The power plant of the S.S. *Examiner* a C-3 type Maritime Commission vessel, consists of two double-furnace boilers supplying steam at 1200 lb, 740 F to an 8000-hp geared turbine unit. By employing the reheat cycle at this pressure and temperature the moisture in the exhaust end of the turbine is kept within permissible limits and a reduction of 12 per cent in heat consumption is attained, as compared with the conventional 425-lb installation.

IN A paper before the Annual Meeting of The Society of Naval Architects and Marine Engineers in New York, November 13 and 14, Benjamin Fox[1] and R. H. Tingey[2] described the high-pressure power plant of the S.S. *Examiner*, one of the Maritime Commission C-3 class of ships now nearing completion at the Bethlehem Plant, Quincy, Mass., for the American Export Lines. Propulsion is by a single screw driven by double-reduction geared turbines of 8000 shaft horsepower which are supplied with throttle steam at 1200 lb, 740 F. This steam is generated by two double-furnace oil-fired boilers each of 35,200 lb per hr capacity, with economizers and air preheaters. Automatic combustion control is installed and the reheat cycle employed; that is, the steam after passing through the high-pressure turbine is returned to the reheater furnace of the boiler and then passes to the intermediate-pressure turbine at 215 lb and 740 F, the low-pressure turbine exhausting at 1.5 in. Hg. The feedwater temperature is 390 F.

This ship is one of eight vessels of a group, the remaining seven employing steam conditions of 425 lb and 740 F at the turbine throttle. The paper makes a comparison of these two sets of steam conditions and discusses the reasons for adopting the reheat cycle for the higher pressure. With 425 lb, 740 F and 28½ in. vacuum without reheat, the moisture in the last stage of the low-pressure turbine would be 11 to 12 per cent, which is within allowable limits; but if reheat were not employed with the 1200-lb, 740-F initial conditions the last-stage moisture would be 15 per cent. which is much too high. Or, if reheat were not employed with the 1200 lb an initial steam temperature of 940 F would have been necessary in order to keep the moisture within the prescribed limits. Hence, the principal advantage of using reheat in this case was the ability to employ higher pressure without increasing the initial temperature above 740 F, but at the same time taking advantage of a gain in the cycle efficiency.

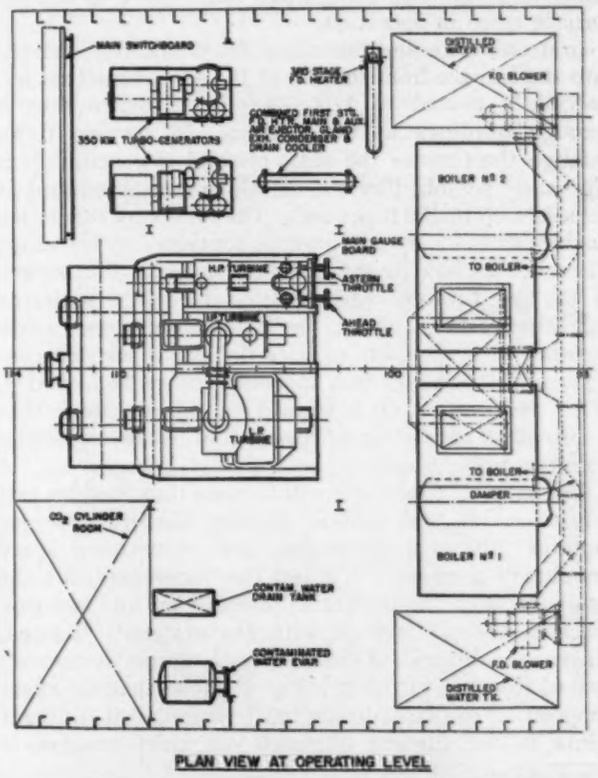
[1] Assistant Manager of Engineering, Bethlehem Steel Co., Shipbuilding Div., Quincy, Mass.

[2] Chief Engineer, Bethlehem Steel Co., Shipbuilding Div., Quincy, Mass.

Among other advantages cited for the 1200-lb pressure was the ability to employ more stages of feedwater heating, in this case four. This shows a gain of about 2 per cent in efficiency which offsets the additional feed pump power required because of the high pressure. It also permits the auxiliaries to be operated with steam bled from the main turbines, after having done useful work. The steam conditions selected show a reduction in heat consumption for the main unit of 12 per cent, as compared with the lower pressure installations, or a net gain for the whole plant of about 11 per cent.

Had steam reheating been selected the arrangement and operation would have been simplified but because of a limiting reheat temperature of about 560 F with steam reheating the plant efficiency would have been 3 per cent less.

With gas reheating it is essential that there be steam flow through the tubes at all times during which the gases



PLAN VIEW AT OPERATING LEVEL

Plan of power plant of the S.S. *Examiner*

are passing over them. This is one of the reasons for the double furnace. Separate astern turbine stages are provided, as is usual in geared installations, and the steam for the astern turbine does not pass through the reheater.

The estimated fuel consumption of the *Examiner* is 0.513 lb of oil per shaft horsepower-hour or a reduction of 12.8 per cent compared with the conventional 425-lb design.

Combustion Calculations by Graphical Methods— BLAST-FURNACE GAS

This is the third article of a series each dealing with a particular fuel, by which, through the use of charts, combustion calculations can be quickly and accurately made. The first article, which appeared in the August issue, dealt with fuel oil; and the second, in the October issue, with coke-oven gas; the next, scheduled for February, will deal with natural gas.

By A. L. NICOLAI

Combustion Engineering Company, Inc.

BLAST-FURNACE gas is one of the most important by-products in the smelting of iron ore to obtain pig iron. Its characteristics are therefore best understood by examining what takes place in a blast furnace when in operation.

Iron ore, coke and limestone are alternately charged into the furnace from the top at the same time that air, previously heated to 1100–1300 F, is blown into it through openings at the bottom. In moving down through the furnace the mass of solid raw materials is vigorously scrubbed by the air which sweeps upward at velocities up to 450 ft per sec. The process of extracting the iron from its ore may now be conceived as beginning when the carbon in the coke unites with the oxygen in the air to form carbon monoxide, CO, with the liberation of heat. Next, the presence of more carbon together with this heat reduces the iron oxide and converts some of the carbon monoxide to carbon dioxide, CO_2. Still more CO_2 is formed by the limestone that is provided to facilitate removal of some impurities from the molten mass.

Referring to Table 1, it will be seen that, besides carbon monoxide and carbon dioxide, blast-furnace gas contains nitrogen, hydrogen and sometimes small amounts of methane. The last two components are the result of high temperature dissociation of moisture which enters the furnace with the materials charged, whereas the nitrogen in the analyses is almost exclusively derived from the air blast. Fig. 1[1] shows that the exact composition of blast-furnace gas is different at different points in the furnace although our chief concern is obviously with the nature of the gas as it becomes available at the boiler plant.

It is noteworthy that whereas a few years ago iron and steel producers wasted much gas and concentrated their entire attention on getting the highest yield of pig iron per ton of coke burned, now they are much more aware of the economic value of a better quality of blast-furnace gas.

Present-day boiler furnaces burn this fuel in any one of three different states: (1) as raw gas with some of the dust and dirt removed; (2) after the gas has had a "primary" cleaning or washing; and (3) after it has been thoroughly dedusted or washed by means of "final" as well as "primary" cleaners.

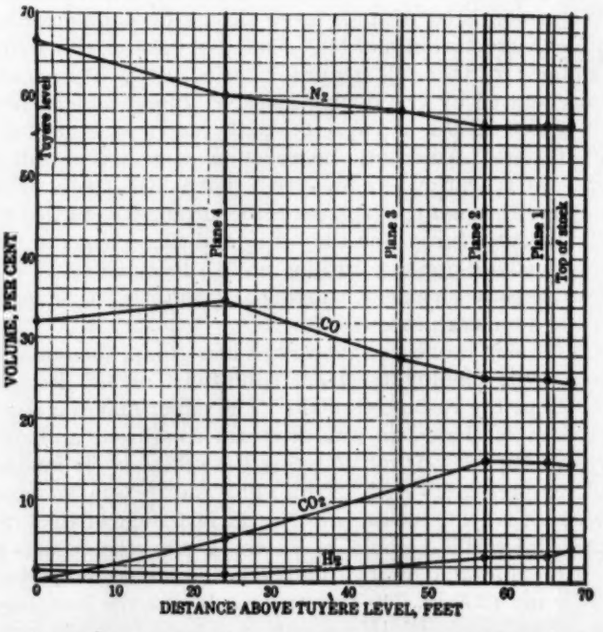


Fig. 1—Composition of gas at various elevations, per cent by volume

[1]Technical Paper 442, U. S. Dept. of Commerce.

TABLE I—CHARACTERISTICS OF TYPICAL BLAST-FURNACE GASES SATURATED WITH MOISTURE AT 62 F AND 30 IN. Hg

% CO_2	% N_2	% CO	% H_2	% CH_4	Density, Lb/Cu Ft	Heat Value Btu/Cu Ft High	Btu/Cu Ft Low	Btu/Lb High	Btu/Lb Low	Atmos. Air at Zero Excess Air Lb/10^4 Btu	CO_2 at Zero Excess Air, Per Cent
14.5	57.5	25.0	3.0	..	0.0775	88.3	86.9	1140	1122	574	26.4
13.0	57.6	26.2	3.2	..	0.0768	92.8	91.2	1208	1188	574	25.7
15.59	59.28	23.35	1.7	0.08	0.0788	79.8	78.9	1012	1002	565	26.9
8.7	56.5	32.8	1.8	0.2	0.0759	111.1	110.0	1463	1449	577	25.3
5.7	59.0	34.0	1.3	..	0.0749	111.3	110.7	1487	1478	573	24.0
6.0	60.0	27.0	2.0	5.0	0.0731	141.1	135.2	1932	1850	627	20.0

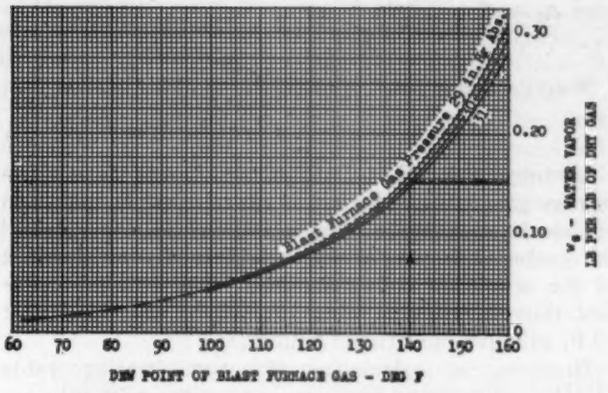


Fig. 2—Water vapor in blast-furnace gas

Dust.—The high velocity with which the blast of air sweeps through the alternate layers of coke, iron ore and limestone causes many fine particles, and some fairly large lumps of these materials, to be carried along in suspension as dust. In some cases as much as 50 grains of dust per standard cubic foot (at 62 F and 30 in. Hg) has been measured in the gas leaving the top of the blast furnace. Plainly, if the gas were to be burned in this state, it would plug up the burners and boiler passages so quickly as to require almost continual shutdowns for cleaning. Generally, therefore, many of the solids in suspension are removed, before firing, by passing the blast-furnace gas through a dry dust catcher. On issuing from this dust catcher as "raw gas," it still contains 3 to 15 grains of dust per standard cubic foot, and, in this condition, it is sometimes burned under steam generating units.

More often, however, before being sent to a boiler furnace the gas is given an additional, or "primary," cleaning by means of either a dry separator or a washer, which brings the dust content down to 0.1–0.8 grain per standard cubic foot.

Further removal of dust, whenever desired, is accomplished with either dry or wet "final" cleaners, which follow the "primary" cleaners and further reduce the dust content to 0.005–0.05 grain per standard cubic foot. In this condition the blast-furnace gas is principally used in gas engines, and only occasionally for steam boilers.

Temperature.—The temperature at which blast-furnace gas reaches the boiler depends on the kind of cleaning apparatus employed. As raw gas coming from the dust catcher, its temperature may be anywhere from 300 to 800 F. If the subsequent cleaning is done with dry separators, the drop in gas temperature through each separator may be only 30 to 50 F. On the other hand, washers, which use sprays of water to precipitate the dust, lower the temperature of the gas to 70–120 F. Furthermore, in some cases the distance from blast furnace to boiler is sufficiently great to cause a drop in temperature due to radiation losses in the connecting pipes.

Moisture.—So far we have made use of the ordinary ways of classifying blast-furnace gas into "raw" gas, gas that has had a "primary" cleaning and gas that has had a "final" cleaning. For purposes of combustion calculations, however, it is found more convenient to speak of "washed" and "unwashed" gas, and these will be the terms most frequently employed in the discussion which follows.

Washed gas is blast-furnace gas that has gone through either primary or final washers. It may be considered as saturated with moisture at whatever temperature it leaves the washer because of the intimate contact between cooling water and hot gas. If the gas has only been given a primary wash, it will contain about four grains (0.00057 lb per standard cubic foot) of entrained moisture in addition to the water vapor required to saturate it. This entrained moisture is carried along by the gas in the form of suspended droplets which are effectively removed by a final cleaner.

Unwashed gas, on the other hand, may exist as raw gas or as gas that has had a primary, or even a final, cleaning by means of dry separators. Its temperature is much higher than that of washed gas and because of this it is capable of holding much more moisture, since it will contain all the water vapor that it had on leaving the blast furnace regardless of its degree of cleaning. Some engineers have recommended to the author the use of a dewpoint of 140 F for calculating the moisture in unwashed gas, but it is obviously preferable to know the actual dewpoint of a particular gas than to assume it. Fig. 2, then, offers a convenient curve for determining w_s, the saturation moisture, for any dew point temperature from 62 to 160 F. There is, of course, no entrained water in unwashed gas.

Density.—The density of blast-furnace gas at 62 F (d_{62}) is easily computed from its volumetric analysis by the method explained in the article on coke-oven gas[1]

[1] See COMBUSTION, October 1941, p. 39.

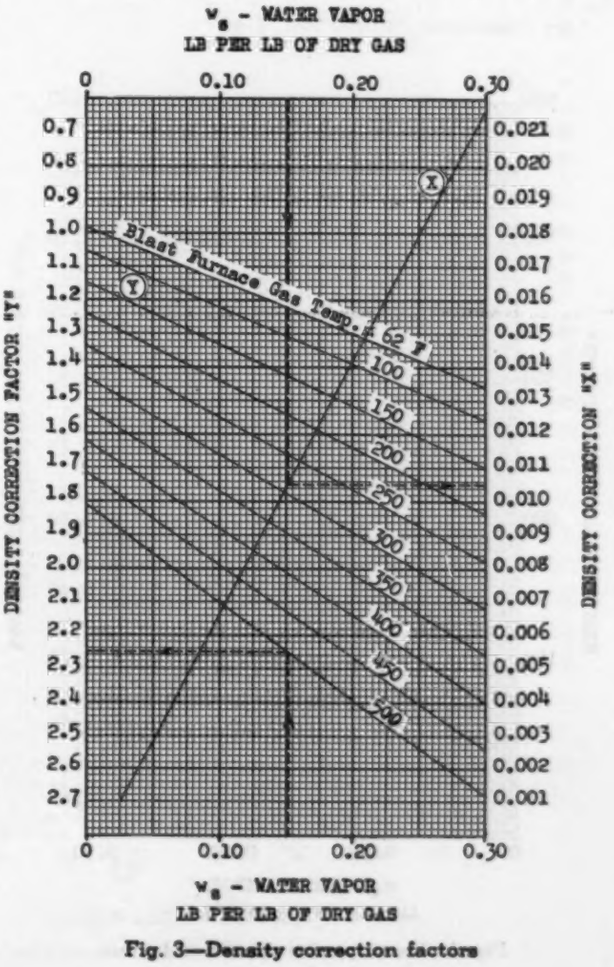


Fig. 3—Density correction factors

which assumes that the gas is clean and saturated with moisture at 62 F. The true density (d_t) is obtained by correcting d_{62} for the actual temperature (t), moisture content and dust according to the following equation:

$$d_t = \frac{d_{62} + X}{Y} + (D_t + w_e) \qquad (11)$$

where:

d_t and d_{62} = density of gas at temperature t and 62 F, respectively, lb per cu ft
X and Y = correction factors read from Fig. 3
D_t = dust content of gas, lb per cu ft at t temperature
w_e = entrained water found only in primary washed gas, lb per cu ft at t temperature

As an example, let us assume that the blast-furnace gas in the first line of Table 1 is unwashed and goes to a burner with 15 grains of dust, at 500 F with a dewpoint of 140 F and at a pressure of 30 in. Hg. What is its actual density if there is no entrained moisture? We proceed as follows:

	Per Cent by Volume, Dry	Volume, Cu Ft per Cu Ft of Gas	Density Lb/Cu Ft Saturated at 62 F*	Weight, Lb/Cu Ft
Carbon dioxide, CO_2	14.5	0.145	× 0.1147	= 0.01663
Nitrogen, N_2	57.5	0.575	× 0.0737	= 0.04238
Carbon monoxide, CO	25.0	0.250	× 0.0733	= 0.01833
Hydrogen, H_2	3.0	0.030	× 0.00604	= 0.00018
Density of clean gas saturated with moisture at 62 F =				0.07752

For a saturation temperature of 140 F and a pressure of 30 in. Hg, read from Fig. 2, w_e = 0.152 lb per lb of dry gas, and from Fig. 3 obtain X = 0.0105 and Y = 2.25. Then the density of clean gas at 500 F and a dewpoint of 140 F will be expressed as

* See COMBUSTION, October 1941, p. 39.

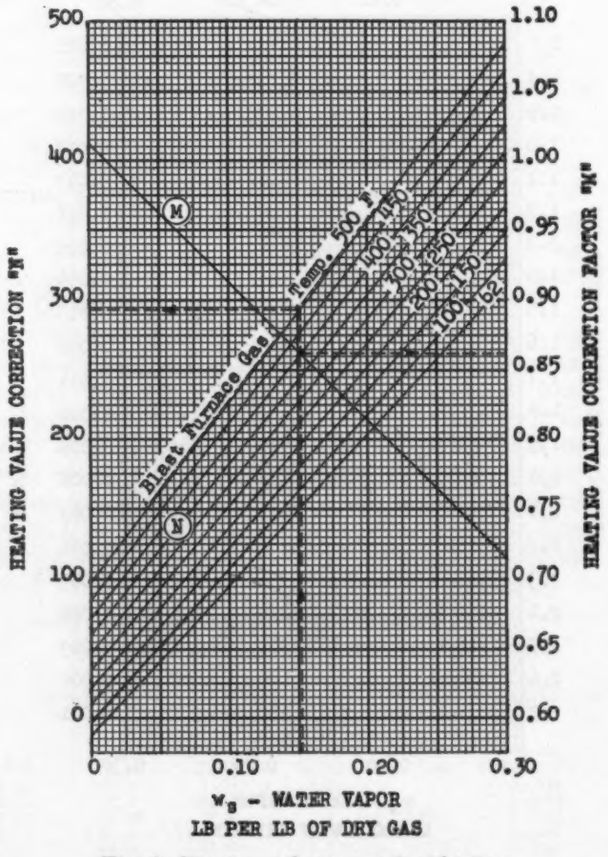


Fig. 4—Heating valve correction factors

$$\frac{d_{62} + X}{Y} = \frac{0.0775 + 0.0105}{2.25} = 0.0391 \text{ lb per cu ft.}$$

$$\text{Weight of dust in gas} = \frac{15}{7000} \times \frac{0.0391}{0.0775} = 0.0011 \text{ lb per cu ft}$$

$$d_t = 0.0391 + 0.0011 = 0.0402 \text{ lb per cu ft}$$

Heating Value.—The Btu per cubic foot of clean blast-furnace gas, saturated with moisture at 62 F, may also be calculated from its analysis and the heating value of its combustible components as obtained from Table 2 of the article on coke-oven gas.[2] The Btu per cubic foot thus determined, when divided by the density at 62 F, will give the Btu per pound $(HHV)_{62}$.

However, in calculating the true heating value $(HHV)_t$, of a gas as fired, we must again take into account its dust content, its temperature and the fact that its dewpoint may be higher than 62 F.

The dust in blast-furnace gas is made up chiefly of particles of iron ore, limestone and coke. There is reason to believe that iron ore is the main component in this mixture, since its structure is sandy or granular, and therefore more easily lifted by the blast than coke or limestone which comes in relatively large lumps. When the dust burns, the coke in it may be thought of as supplying the heat required to reduce both ore and limestone. In the absence of actual tests showing the calorific value of the dust, it may be assumed that the heat evolved by the coke is just equal to that required to reduce the ore and the limestone. If this is true, the heating value of blast-furnace gas will not be influenced by the presence of dust.

It should also be clear that any increase in the temperature of the gas above 62 F is bound to enhance its heating value by an amount equal to the sensible heat of the gas above 62 F.

Furthermore, let us, as an example, assume that an unwashed gas is saturated at 140 F. It will then have 0.138 lb of additional moisture for each pound of gas saturated at 62 F. As an inert vapor, this increase in moisture will reduce the combustible fraction and therefore the heating value of blast-furnace gas, at the same time that it augments the heating value by the sensible heat due to its high temperature.

Having obtained the Btu per pound $(HHV)_{62}$, as though the unwashed gas were saturated with moisture at 62 F, the following expression enables us to figure the Btu per pound $(HHV)_t$, at its true temperature, t.

$$(HHV)_t = M(HHV)_{62} + N \qquad (12)$$

Knowing the actual dewpoint of this gas, w, is read from Fig. 2, and M and N from Fig. 4 before using them in equation (12).

Fuel, F.—It was seen that a mean value of F = 57 lb per million Btu could be assumed for all coke-oven gases[2] without introducing appreciable error in its products of combustion. This simplified procedure cannot be used for blast-furnace gas because of the varied conditions in which it is sent to boiler furnaces. However, after determining the true Btu per pound, as in the preceding section F, which is that portion of the fuel that shows up in the products of combustion, may be read from Fig. 1 of the first of these articles on combustion calculations.[3] In determining F with the aid of Fig. 1, any dust in unwashed gas may be treated as ash in coal or sediment in oil would be.

[3] COMBUSTION, August 1941.

Atmospheric Air, A.—For clean blast-furnace gas, saturated with moisture at 62 F, the atmospheric air, A in pounds per million Btu may be read from Curve A, Fig. 5, for any value of excess air up to 70 per cent.

Curve A, likewise, must be corrected for the dust, moisture content and temperature of the actual blast-furnace gas. After getting A from Fig. 5, the factor Y from Fig. 3 and the heating value and density as explained in the preceding sections, the true pound of atmospheric air per million Btu as fired is

$$A_t = \frac{A}{Y} \frac{(HHV)_{62}}{(HHV)_t} \frac{d_{62}}{d_t} \qquad (13)$$

Total Products, P.—As with other fuels previously discussed, the weight of the products of combustion is given by $P = F + CA$ lb per million Btu as fired.[3] This equation holds true for either washed or unwashed gas, provided F and A are calculated as explained in the foregoing sections.

Moisture from Fuel, W_f.—As defined in the first article,[3] W_f is the total amount of water vapor present in the products of combustion.

In blast-furnace gas there are three different sources of moisture that eventually become part of the products. First, there is the moisture which is formed in burning

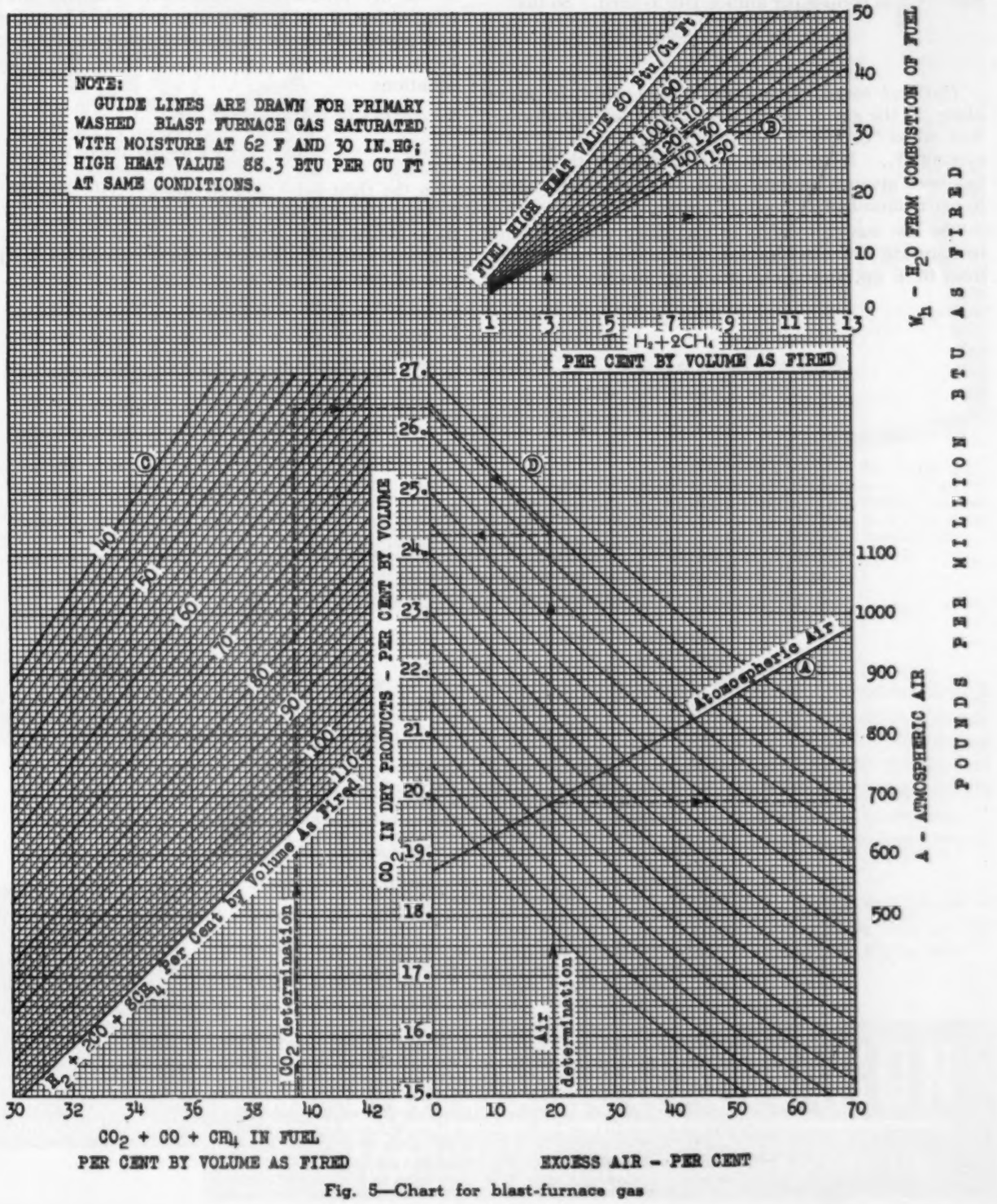

NOTE:
GUIDE LINES ARE DRAWN FOR PRIMARY WASHED BLAST FURNACE GAS SATURATED WITH MOISTURE AT 62 F AND 30 IN.HG; HIGH HEAT VALUE 88.3 BTU PER CU FT AT SAME CONDITIONS.
FUEL HIGH HEAT VALUE 80 Btu/Cu Ft.
90
100
110
120
130
140
150
$W_h - H_2O$ FROM COMBUSTION OF FUEL
H_2+2CH_4
PER CENT BY VOLUME AS FIRED
CO_2 IN DRY PRODUCTS - PER CENT BY VOLUME
Atmospheric Air
A - ATMOSPHERIC AIR
POUNDS PER MILLION BTU AS FIRED
$H_2 + 2CO + 3CH_4$ Per Cent by Volume As Fired
CO_2 determination
Air determination
$CO_2 + CO + CH_4$ IN FUEL
PER CENT BY VOLUME AS FIRED
EXCESS AIR - PER CENT

Fig. 5—Chart for blast-furnace gas

the fuel and previously designated by W_h.[3] For clean gas, saturated with moisture at 62 F and 30 in. Hg,

$$W_h = \frac{46{,}700\ (H_2 + 2CH_4)}{\text{Btu per cu ft at 62 F and 30 in. Hg}} \qquad (14)$$

Curves B of Fig. 5 are plotted from equation (14).

If the actual gas is at a temperature higher than 62 F and contains dust and moisture in excess of what was assumed in plotting Curves B, the readings from Curves B must be multiplied by the same factor used in correcting the atmospheric air, in order to obtain the true moisture $(W_h)_t$ in pounds per million Btu as fired. So that

$$(W_h)_t = \frac{W_h}{Y} \frac{(HHV)_{62}}{(HHV)_t} \frac{d_{62}}{d_t} \qquad (15)$$

The next source of moisture is that which is carried along by the gas in the form of suspended globules and was called "entrained moisture." To this we give the symbol W_e. It need only be considered with gas that has been given a primary wash, in which it averages 7 lb per million Btu.

The last source consists in the water vapor required to saturate the blast-furnace gas at any temperature from 62 F up, as the case may be, and which may be designated as W_s. Ten pounds per million Btu may be assumed for W_s without causing any serious error in the heat balance. This moisture must be considered separately from W_h and W_e in a heat balance since it exists as a vapor requiring no latent heat of vaporization. It would be more appropriate to set it up as a separate item in the heat balance.

Of course, W_s must be subtracted from the total products, along with W_h and W_e, to obtain the dry gas.

Per Cent CO_2 in Products.—Curves C and D of Fig. 5 offer a convenient method of getting the per cent of CO_2 in the dry products of combustion resulting from the combustion of either washed or unwashed blast-furnace gas, provided the dry volumetric analysis of the gas is known. Curves C are plotted from the following equation:

$$\text{Per cent } CO_2 \text{ (at zero excess air)} = \frac{100(CO_2 + CO + CH_4)}{100 + 0.928(H_2 + 2CO + 8CH_4)} \qquad (16)$$

In the right-hand side of equation (16) the H_2, CO_2, CO and CH_4 are the symbols for per cent by volume of these constituents in the fuel. This CO_2 must not be confused with the present carbon dioxide in the dry products of combustion.

Blast-Furnace Gas

(See chart on reverse side)

EXAMPLE

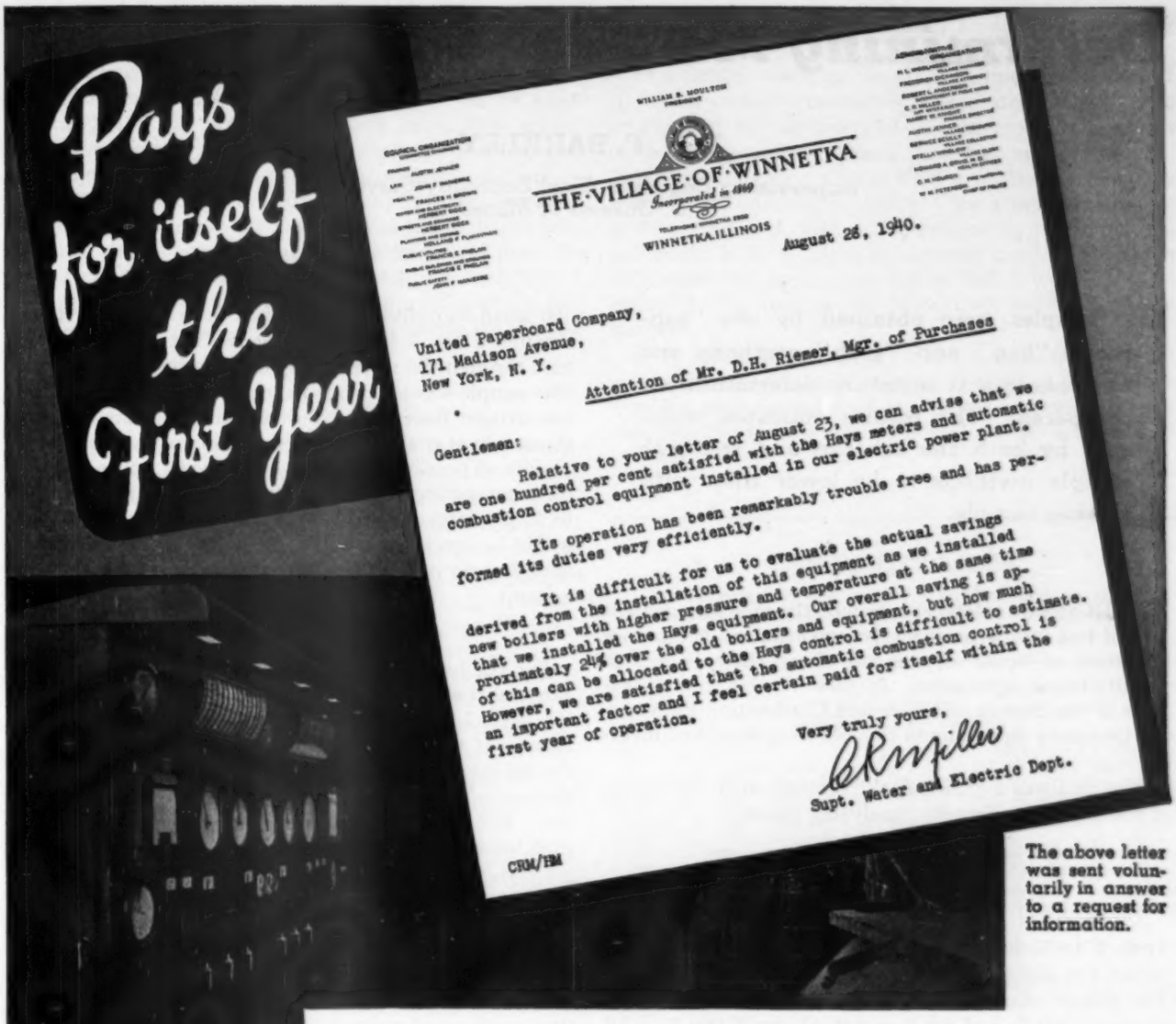
Assume a blast-furnace gas of the typical analysis listed first in Table 1 to be saturated with moisture at 62 F and burned with 20 per cent excess air, after going through a primary washer. Then,

1. *Fuel, F.* For a high heat value of 1140 Btu per lb and a negligible amount of dust refer to Fig. 1 of the August 1941 article in COMBUSTION, and from it read $F = 876$ lb per million Btu.
2. *Atmospheric Air, A.* From Curve A, Fig. 5, for 20 per cent excess air read $A = 690$ lb per million Btu.
3. *Unburned Combustible.* The general assumption when burning blast-furnace gas in stationary boiler furnaces is that the combustible loss is zero. Consequently, C in equations (3) and (4)[3] may be taken as 1.
4. *Total Products, P.* From equation (4),[3] $P = F + CA = 876 + 1 \times 690 = 1566$ lb per million Btu.
5. *Moisture in Air, W_a.* From equation (5),[3] $W_a = 0.013A = 0.013 \times 690 = 9$ lb per million Btu.
6. *Moisture from Fuel, W_f.* As pointed out before for a gas that has passed through a primary washer, $W_e = 7$ lb per million Btu. Curves B, Fig. 5, show $W_h = 16$ lb per million Btu for a blast-furnace gas with a high heat value of 88.3 Btu per cu ft, and $H_2 + 2CH_4 = 3 + 0 = 3$ per cent by volume as fired. Therefore

$$W_f = W_a + W_e + W_h = 10 + 7 + 16 = 33 \text{ lb per million Btu}$$

7. *Dry Gas, P_d.* From equation (7),[3] $P_d = P - (W_a + W_f) = 1566 - (9 + 33) = 1524$ lb per million Btu.
8. *Per Cent CO_2 in Products.* From the fuel analysis calculate $CO_2 + CO + CH_4 = 14.5 + 25.0 + 0 = 39.5$ per cent by volume and $H_2 + 2CO + 8CH_4 = 3 + 2 \times 25 + 8 \times 0 = 53$ per cent by volume, and from Curves C, Fig. 5 read 26.4 per cent CO_2 at zero excess air. Following Curves D as guide lines to 20 per cent excess air, read $CO_2 = 24.3$ per cent.

Pays for itself the First Year



THE·VILLAGE·OF·WINNETKA
Incorporated in 1869
WINNETKA, ILLINOIS

August 26, 1940.

United Paperboard Company,
171 Madison Avenue,
New York, N. Y.

Attention of Mr. D.H. Riemer, Mgr. of Purchases

Gentlemen:

Relative to your letter of August 23, we can advise that we are one hundred per cent satisfied with the Hays meters and automatic combustion control equipment installed in our electric power plant.

Its operation has been remarkably trouble free and has performed its duties very efficiently.

It is difficult for us to evaluate the actual savings derived from the installation of this equipment as we installed new boilers with higher pressure and temperature at the same time that we installed the Hays equipment. Our overall saving is approximately 24% over the old boilers and equipment, but how much of this can be allocated to the Hays control is difficult to estimate. However, we are satisfied that the automatic combustion control is an important factor and I feel certain paid for itself within the first year of operation.

Very truly yours,

Supt. Water and Electric Dept.

CRM/HM

The above letter was sent voluntarily in answer to a request for information.

A MUNICIPAL light plant in a mid-western city, through a modernization and expansion program including Hays Automatic Combustion Control, improved its operating efficiency around 24%. Steam pressure was raised from 225 lbs. to 450 lbs., total temperature from 500° F. to 750° F. and fuel consumption per kw.-hr. output was reduced from 2.32 lbs. to 1.73 lbs. Efficient and economical combustion with practically no smoke or fly-ash is maintained by the Hays Automatic Control as well as a constant steam pressure regardless of load fluctuations.

Hays Engineering organizations throughout the country are ready to advise you how automatic combustion control may be able to improve the operating conditions in your own power plant—no obligation. Write us.

NOTE TO ENGINEERS:

Tear off the bottom of this ad and mail with your name and address to Hays Corporation and we will send you a copy of "Automatic Combustion Control and its Relation to Lower Steam Costs."

The HAYS CORPORATION

SINCE 1901 — COMBUSTION INSTRUMENTS AND CONTROL — MICHIGAN CITY, INDIANA, U.S.A.

Determining Moisture Content of Coal*

By J. F. BARKLEY

Supervising Engineer, Fuel Economy Service,
U. S. Bureau of Mines

Samples were obtained by the "ash-can," "bag" and "grab" methods and the consequent moisture determinations compared. The results indicated moisture by both the ash-can and the grab sample methods to be lower than with the bag sample.

THE accurate determination of the moisture content of test coal is particularly important on acceptance tests of boiler equipment where there is a high penalty-bonus agreement. In view of this, representatives of the Bureau of Mines and Combustion Engineering Company agreed upon the following described methods:

The coal was a $^3/_4$-in. slack, Pennsylvania "E" seam, of fairly good uniformity, analyzing about

H_2O, as fired..... 3.3 per cent
Volatile, dry basis.....24.4 per cent
Ash, dry basis.....10.2 per cent
Btu, dry basis.....13,930

Tests 1 to 7, inclusive, reported in the accompanying tables, ran about 23 hr, and Tests 8 and 9, about 12 hr. The weight of coal used per hour for Tests 1 to 7 was about 11,300 lb and for 8 and 9, about 20,000 lb. All samples were analyzed by the Bureau of Mines.

Three types of moisture samples were taken and designated: "ash-can," "bag" and "grab" samples. The ash-can sample was representative of usual sampling procedure. For Tests 1 to 7, nine small shovelfuls of coal weighing about $1^1/_4$ lb each were taken at every half hour from a moving coal stream carried on a belt conveyor. It required about three minutes to accumulate this total increment of approximately 11 lb. The coal as taken was immediately placed in 200-lb ash cans with tight fitting lids and the cans were kept at ordinary room temperature. The number of shovelfuls per half hour was doubled on Tests 8 and 9.

At the end of each test, there was accumulated one sample of coal weighing around 500 lb, made up of about 400 small shovelfuls. All of the coal was then screened through a No. 4 screen, the pieces that at first did not pass through the screen being crushed by hand tampers. The sample was next riffled and reduced to fill the standard airtight Bureau of Mines shipping container holding about 3 lb of coal. The field reduction work was done as rapidly as possible in a space in the boiler house and at a room temperature of about 70 F, the humidity being 30 to 40 per cent. It was considered at the time that there would be loss of moisture in reducing the sample in the field, but no information was at hand as to its probable amount.

Taking Bag Sample

For the bag sample, an ordinary heavy-grade pillowcase was used, holding about 32 lb of coal. At each hour for Tests 1 to 7, 16 lb or one-half a bagful of coal was taken. It was accumulated in a few minutes, similar to the taking of the ash-can sample. During the wait for the second half-bagful, the bag was placed in an airtight can. For Tests 8 and 9, one bagful of coal was taken at each hour. There were, therefore, 11 or 12 bag samples per test, or a total of 350 to 380 lb of coal per test. The filled bag was immediately weighed in grams for a gross weight, the tare having been previously determined. It was then placed on a walk grating near a boiler to dry. The temperature at this spot was 85 to 90 F. At the end of approximately two days (the exact time depending on the constancy of weight) it was taken to a rack at ordinary room temperature for 36 hr or more until the weight became constant. The coal from three or four bags in consecutive order was then thrown together, screened, crushed, riffled and reduced on the job to the standard shipping container. Three such samples were sent to the laboratory per test. It was considered that there would be little or no moisture change in reducing in the field a sample that had been air-dried at room temperature.

TABLE 1—MOISTURE CONTENTS OF COAL SAMPLES

	Moisture Content, Per Cent										
Test No.	1	2	3	4	5	6	7	8	9	Ave.	Diff.
Ash-can samples	2.4	2.9	3.5	2.5	2.3	2.3	2.4	2.7	2.9	2.66	
Grab samples of ash-can samples	2.8	3.1	3.7	2.6	2.8	3.0	3.5	2.8	3.5	3.09	0.43
Grab samples of bag samples	2.7	2.9	3.6	2.6	2.6	2.8	3.1	3.1	3.4	2.98	0.11
Bag samples	2.8	3.0	3.8	3.1	2.9	2.8	3.5	3.7	3.7	3.26	.28
									Diff. between bag and ash-can samples		.60

Grab Sample

The grab sample consisted of six to eight increments of $^1/_2$ to $^3/_8$ lb each, or a total of approximately 3 lb of coal. These samples were taken in conjunction with the ash-can and bag samples. A grab sample was taken of each ash-can sample just before its reduction in the field; a grab sample was taken of each bag sample while it was

* Published by permission of the Director of the Bureau of Mines.

being collected; and, with the exception of Test 1, a grab sample was also taken of each air-dried composite of the three or four bag samples just before their field reduction to the shipping container. The six to eight increments of the grab sample were taken from representative spots in the coal mass being sampled and put directly into the shipping container without crushing.

Table 1 shows the moisture content as reported by the laboratory of the ash-can samples and the moisture content of their corresponding grab samples. There are also given the average moisture content for each test of the grab samples taken of the bag samples and the calculated final moisture for each test as shown by the bag samples.

Lower Moisture in Ash-Can Samples

The moisture content of the ash-can samples consistently ran lower than that of their corresponding grab samples. The two sets of grab samples ran close together, the difference between their averages being 0.11 per cent. Since there were at least eleven bag samples per test and only one ash-can sample, the set of grab samples taken of the bag samples was made up of at least eleven times as many increments as those taken from the ash-can samples. In a general comparative study, therefore, their accuracy would be considered of a higher order. The moisture content of the bag samples ran consistently higher than that of their corresponding grab samples, with the exception of Test 6, for which it was the same. With a few exceptions, the moisture content of the bag samples was consistently higher than that of any of the other samples.

The only essential difference in the general procedure of reduction and analyzing between the grab samples for the tests and the ash-can samples was the reduction of the ash-can samples in the field. The average difference, therefore, between their moisture contents indicates the extent of the loss from the reduction of the sample in the field. This average difference for each test is 0.32 per cent, as shown by the better set of grab samples, or 0.43 per cent, as shown by the other set.

TABLE 2—MOISTURE CONTENTS OF AIR-DRIED BAG SAMPLES AND CORRESPONDING GRAB SAMPLES

Item	Moisture Content, Per Cent											
Bag	0.8	1.0	1.0	0.8	0.8	0.9	0.9	1.0	0.8	1.1	1.0	1.1
Grab	1.0	1.0	1.0	.9	1.0	1.0	.9	.8	.8	1.1	1.0	1.0
Bag	1.1	.8	1.1	1.0	1.1	1.2	1.1	.6	.9	.6	1.0	1.0
Grab	1.1	.8	1.1	1.0	1.0	.9	1.0	1.0	1.1	1.5	1.1	.9
Bag	Ave. 0.95											
Grab	Ave. 1.00			Diff. 0.05								

A small loss of moisture from the handling in the laboratory appears to be indicated. The grabs of the bag samples went to the laboratory containing on the average about 3 per cent moisture. The bag samples underwent reduction both in the field and in the laboratory while containing on the average only about 1 per cent moisture brought, in so far as possible, to a balanced condition at ordinary room temperature. If it is assumed that no loss of moisture resulted either in the field or the laboratory due to reduction for the bag samples, the lower moisture content of the grabs could be attributed to the moisture loss due to their handling in the laboratory. The amount as shown is 0.28 per cent. Since the coal appeared fairly dry, the procedure used in the laboratory was to dump the contents of the shipping container as received directly onto a weighing pan. It was then weighed, air-dried and reweighed to determine loss of moisture.

As a further check on the above assumptions, Table 2 shows the moisture content of field air-dried bag samples as reported by the laboratory. The moisture contents of the grab samples taken of these bag samples just before their reduction in the field are also given. Test numbers are omitted for clarity. The average agreement is very good and, with a few exceptions, the individual agreement in each case is consistently good. Loss in the field reduction appears negligible, which would also be expected therefore in the laboratory handling of the samples.

If the moisture content of the bag samples is considered correct for the coal, the moisture content of the ash-can samples as indicated from the tables averages 0.60 per cent low and that of the better set of grab samples 0.28 per cent low.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales
Stationary Power Boilers

	1941 Water Tube		1940 Water Tube		1941 HRT Type		1940 HRT Type	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.....	170	968,275	62	285,042	89	123,459	51	68,639
Feb.....	102	896,763	54	386,356	81	104,622	47	51,474
Mar.....	133	938,605	56	438,980	86	89,324	51	58,529
April.....	159	802,993	89	476,135	129	151,636	56	50,356
May.....	134	850,659	101	663,721	114	154,964	75	84,094
June.....	141	743,762	150	814,210	114	134,880	110	122,026
July.....	184	1,184,984	111	632,373	94	121,884	89	128,784
Aug.....	115	780,119	118	685,212	91	101,284	90	108,680
Sept.....	‡121	‡878,996	145	944,970	61	63,385	63	65,218
Oct.....	147	886,346	127	696,993	89	96,740	106	124,876
Jan.-Oct. Incl.	1406	8,931,502	1,013	6,023,992	948	1,142,178	738	862,676

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period January to October (incl.) 1941, 91,380,000 lb per hr; in 1940, 63,312,000 lb per hr.

†Mechanical Stoker Sales

	1941 Water Tube		1940 Water Tube		1941 Fire Tube		1940 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan....	77	41,975	24	10,770	94	14,036	104	14,745
Feb....	60	27,736	31	10,729	117	14,774	118	17,862
Mar....	69	31,342	35	17,460	146	21,552	76	12,717
Apr....	75	34,882	36	14,554	147	20,555	87	15,123
May....	90	43,971	73	30,930	144	19,267	88	11,402
June...	136	50,896	65	15,772	264	42,619	153	21,736
July...	113	50,108	86	31,199	290	40,943	189	37,227
Aug....	96	41,882	78	26,202	391	49,547	274	32,209
Sept....	83	33,663	81	39,799	335	49,559	305	41,038
Oct....	57	21,269	92	38,107	344	54,027	318	42,317
Jan.-Oct. Incl.	856	377,674	601	236,522	2,272	326,879	1,714	236,376

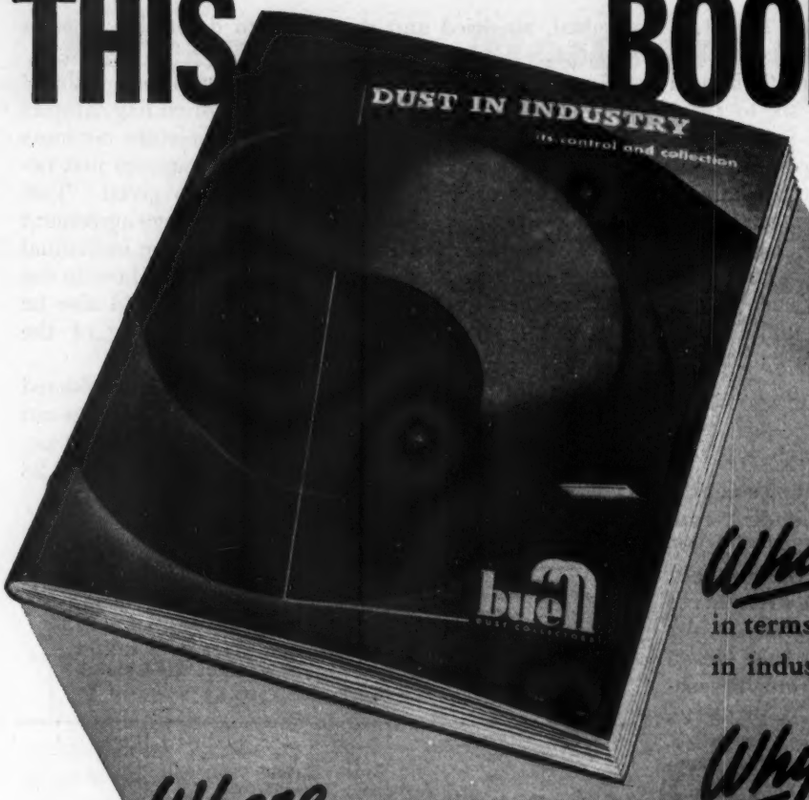
† Capacity over 300 lb of coal per hr.

Pulverizer Sales

	1941 Water Tube No.		Lb	1940 Water Tube No.		Lb	1941 Fire Tube No.		Lb	1940 Fire Tube No.		Lb
	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr
Jan...	39	—	462,990	10	—	214,250	—	1	1,000	1	—	600
Feb...	42	4	734,200	15	1	186,935	—	—	—	1	2	2,800
Mar...	‡31	3	‡739,700	17	1	317,800	—	—	—	—	—	—
April..	14	8	225,740	26	5	270,500	1	—	2,800	—	—	—
May..	54	10	777,320	30	5	447,450	—	4	7,000	—	—	—
June..	28	24	523,540	21	2	360,270	—	1	1,000	—	—	—
July..	57	7	828,640	22	2	454,400	—	1	600	—	—	—
Aug...	30	5	456,480	37	—	705,860	—	1	800	—	—	—
Sept...	38	2	468,930	37	3	1,208,960	—	—	—	1	—	2,800
Oct....	60	—	875,120	26	3	405,430	—	—	—	—	—	—
Jan.-Oct. Incl.	393	63	6,092,660	241	22	4,571,855	1	8	13,200	3	2	6,200

(N)—New Boilers; (E)—Existing Boilers. ‡ Revised.

THIS BOOK TELLS...



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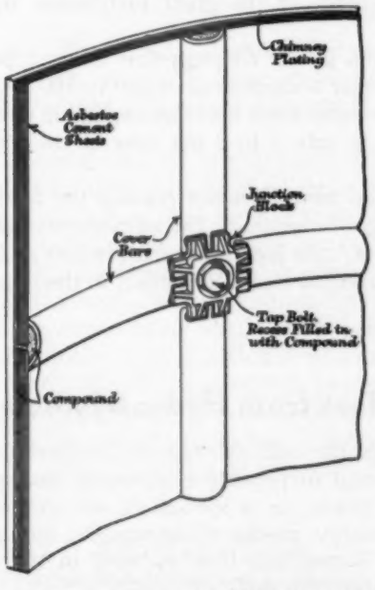
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Preventing Corrosion in Steel Stacks

A. V. Staniforth in *Engineering* (London) of September 12, 1941, describes a type of construction that is now being applied in England to minimize or prevent corrosion in steel stacks. To begin with, the seams are welded instead of being lapped and riveted. The lining consists of asbestos-cement sheeting with a plastic compound between the sheeting and the steel plates. This compound remains in the plastic state up to about 600 F and does not become hard or fluid. Cover bars are placed over the joints to hold the asbestos-cement sheets in place. It is concerning these bars and their holding in place that special interest attaches.

Bars of non-ferrous metals were first tried out, but they did not prove satisfactory due to lack of mechanical strength and in some cases they were attacked by fumes. They were then replaced by flat steel strips secured at the



Sketch showing method of attaching of asbestos-cement sheets

ends by steel studs, the heads of which were sand-blasted and sprayed with non-ferrous metal coatings, but these coatings were practically destroyed in about twelve months and also were expensive to put on.

The next and final step was to provide cast-iron junction blocks having lugs under which the ends of the 2-ft steel strips, with a semi-circular lip, were slipped. These cast-iron junction blocks, as shown in the sketch, are ribbed and secured to the stack by steel studs, the heads of which are recessed in the blocks. These recesses are filled with the plastic compound which is also forced into the hollow spaces between the cover bar and the asbestos sheets, thus forming an effective seal. The construction permits movement under the influence of chimney stresses and movement due to wind.

The lining and compound together take up only $^{5}/_{8}$ in. of thickness and the total weight of the stack, including lining, bars, compound and blocks, is increased about one-third in the case of $^{3}/_{8}$-in. plate construction. Also the lining has an insulating effect and the period during which the temperature in the stack falls below the dew-point is decreased. Tests showed that, with a gas temperature of 290 F, the outside temperature of an unlined stack was 210 F whereas with the lined stack the corresponding temperature on the outside was 150 F. It is pointed out that this lower outside temperature reduces maintenance by increasing the life of the paint.

Deposits on Turbine Blades

The results of an investigation of salt and silica deposits in steam turbines, conducted by the Union of Large Boiler Owners and the I. G. Farben Industry, are reported and discussed by H. Goerke in *Elektrizitätswirtschaft*, No. 25.

It was found that although such deposits occur at both low and high pressures, with the former the action is relatively slow and removal can usually be effected during regular overhaul periods, whereas with the latter it is so rapid as to require attention in many cases after about 100 hr operation. Furthermore, the composition of the deposits with pressures up to about 570 lb was found to consist largely of calcium carbonate and soluble salts; but with higher pressures the insoluble deposits consisted principally of silicic acid and sometimes calcium carbonate; the soluble deposit being primarily sodium chloride with some sodium hydroxide, sodium silicate, sodium carbonate and occasionally sodium sulphate.

The deposition of the separate salts was found to depend on steam temperature ranges. For example, free silicic acid or silicate deposited in appreciable amounts at temperatures from about 350 to 535 F. The salt deposits appeared to be associated primarily with sodium hydroxide and this it is recommended should not exceed 10 to 25 ppm. The boundary above which deposit of silica occurs is probably 5 to 10 ppm of silicon dioxide in the boiler water.

Corrosion in Boiler Feed Pumps

In an article which appeared in the May 1941 issue of *Wärmewirtschaft* (Berlin), H. Goerke states that due to the fact that corrosion and erosion, particularly by steam formation, in boiler feed pumps has been accredited chiefly to high feedwater temperature, present trends in Germany favor a return to temperatures about 105 C

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Service: Pressure Relief to Atmosphere												✔	✔	✔	✔				✔		✔	
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Service: Vacuum Relief		✔	✔	✔	✔	✔																
Service: Pump By-Pass	✔							✔														
Service: Protection of Major Equipment										✔	✔					✔	✔	✔	✔	✔	✔	✔
Max. Relief Pressure	100	150	30	125	50	100	200	150	500	50	15	500	20	20	20	Atmos.	Atmos.	Atmos.	10	Atmos.	10	250
Single Seat	✔				✔	✔	✔			✔	✔					✔	✔	✔	✔	✔	✔	✔
Double Seat		✔	✔	✔			✔	✔	✔			✔	✔	✔	✔							
Diaphragm Actuated	✔	✔	✔	✔	✔	✔		✔														
Piston Actuated									✔													
Direct Disc Actuated										✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Auxiliary Pilot Control							✔					✔										
Spring Loaded	✔	✔				✔	✔	✔	✔	✔	✔	✔										✔
Weight Loaded			✔	✔	✔								✔	✔	✔				✔		✔	
Range of Sizes, Scr'd.	⅜"-2"	½"-4"	½"-4"	½"-4"	½"-4"	½"-4"	½"-4"	½"-4"	½"-4"	2"-6"	2"-6"	½"-14"	2"-6"	2"-6"	2"-6"							
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Material Specifications: Body: Bronze	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔										
Material Specifications: Body: Semi-Steel	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Material Specifications: Body: Steel	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔										
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Material Specifications: Trim: Monel	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔										
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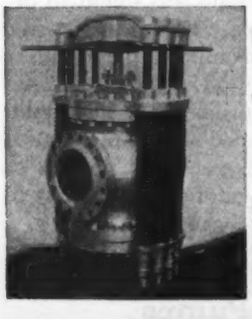
Above—No. 80 "Noiseless" semi-balanced Back Pressure Valve for exhaust lines.



Right—No. 110 Exhaust Relief Valve for condenser protection service.

Left—No. 265 Turbine Bleeder and High Pressure Relief Valve.

DAVIS REGULATOR CO.

(221 F) for feedwater entering the pumps. However, the author contends that this damage may have occurred in plants operating with still lower temperatures, whereas some plants with higher temperatures have operated without damage.

Using feedwater at higher temperatures has, according to the author, the following disadvantages: Corrosion occurs at too low a pH value. The pH drops with increased temperature, i.e., a pH value which is low for cold water will become so low at high temperature as to cause corrosion. A chart shows the relation of pH value and water temperature. The drop in pH value for a temperature rise from zero to 100 C is far greater than from 100 to 200 C, but corrosion is much greater at the lower pH values.

The pH value of the feedwater may be adjusted by the addition of sodium hydroxide or trisodium phosphate and also ammonia, but at the cost of increasing the salt content of the boiler water. If the pH value be limited by the boiler, the pump must be constructed to resist corrosion, whereupon difficulties occur at the seals for the runners and at the throttle of the pressure-relieving disk, since corrosion-resisting materials have poor running qualities and tend to seize at close clearances of 0.2 to 0.3 mm.

With high-pressure pumps of small capacity, having fast-running impellers with high water velocities and high pressure differences between stages, there may be erosion at turns because of the great turbulence and pressure drop.

Feed pump power consumption drops 1 per cent for a drop in water temperature of 150 to 100 deg C. However, this consideration becomes negligible when the total pump load is only 1 to 2 per cent of the main turbine load.

The author also discusses placing the feed pumps at various stages of heating; the advantage of degassing at low pressures; the locations of feedwater storage tanks; and the dangers of steam formation in the pump.

Stored Heat from Hydro Systems

Because of the coal shortage in Switzerland an interesting proposal to provide electroheat storage with hydroelectric power, or a system of winter heating with electrical energy produced during the summer, is described by P. Seehaus (Switzerland) in the April 1941 issue of *Wärmewirtschaft*.

According to this authority, the unused excess of water normally flowing past the hydroelectric plants, during the summer months, is to be put to use generating electrical energy which will be stored in the form of heat for the winter months. Heat storage seems preferable to hydraulic storage, since 1 cu m of water held in storage basins will, when falling 367 meters, deliver 367,000 m-kg, or 1 kwhr, whereas 1 cu m of water, having an available 70 deg C drop in temperature, represents the equivalent storage of 81 kwhr.

Either water or a solid may be used as the medium of heat storage, but the storage of heat must be efficient as conditions call for storage over a considerable period of time.

A water reservoir of 3000 cu m, as shown in Fig. 1, is sufficient for heating about 26 residences during the

winter; i.e., about 110 to 120 cu m per residence. The reservoir may be built of reinforced concrete or of steel insulated with a granulated cork layer of about 40 cm thickness. Assuming a transfer rate of 0.0705 kcal/hr, an annual reservoir temperature of 60 C, an outside temperature of 7 C and a temperature drop of 70 deg C, the efficiency will be 85.4 per cent. The cost of heating would be about 5.5 per cent higher than prewar costs when fired with fuel.

Water reservoirs are believed to be particularly suited for decentralized heat distribution. Where hundreds of thousands of homes are to be supplied, the mass of earth immediately below earth's surface may be used as the

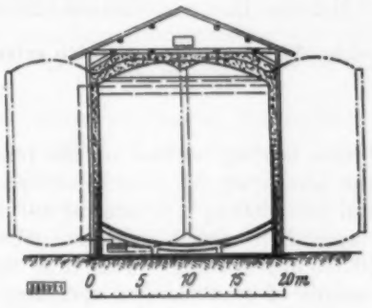


Fig. 1—Water heat reservoir of 3000 cu m capacity. The cellular construction permits later enlargement

heat storage medium. It is claimed the advantage of this system lies in the unusually large storage layouts that may be used within a practical distance from the heat consumers.

For an assumed case of say, about 1400 residences, the heat reservoir shown in Fig. 2 should be sufficient. A half spherical-shaped mass of earth or stone is penetrated with vertical tubes which are closed at the bottom end, filled with water and provided with electrodes. When charging the reservoir, the heat transmitted to the water flows into the surrounding earth for a period totaling about three months, until a sufficient uniformity of heat distribution is attained. Limestone, sandstone, gravel and the like are good heat carriers. For very large reservoirs, granite, porphyritic rock, basalt and the like may be used. To unload this type of reservoir, cold water is

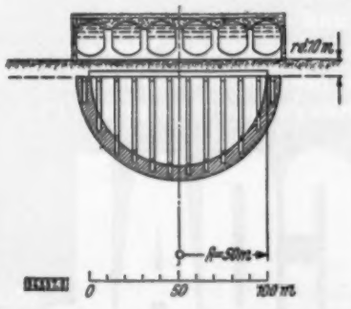
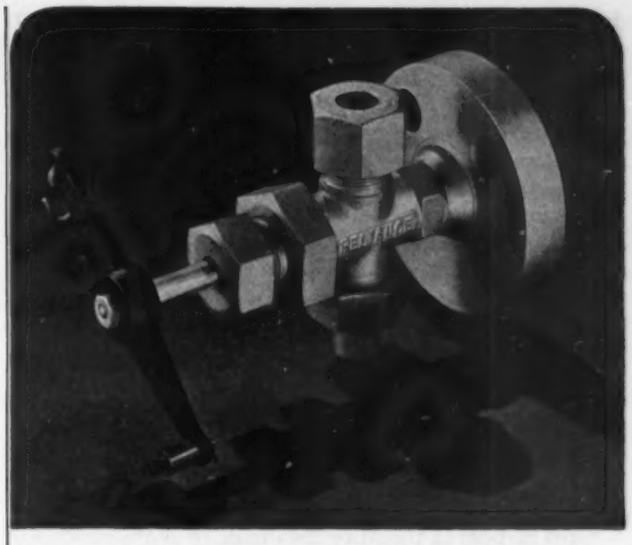


Fig. 2—Arrangement of an earthen heat reservoir. Annual useful heat storage $= 11.25 \times 10^9$ kcal for limestone base

pumped through the vertical tubes and allowed to absorb the stored heat from the surrounding earth.

In calculating the earth storage reservoir, an outer zone 7.5 m thick is assumed surrounding the central



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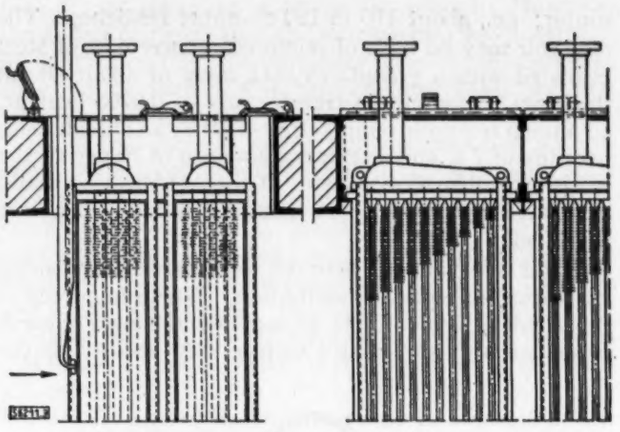
hemispherical zone, which, when unloading the reservoir, yields a portion of the heat received during charging to the central zone. There must be no underground streams of water flowing through either the central zone or the outer zone, though stationary water is not considered objectionable. Large quantities of rain water must be diverted. Heat loss from the ground surface may be overcome by a cellular water storage structure (see Fig. 2) or by insulation.

Calculations, it is claimed, show that after a heating period of three months in the first year, an efficiency of 88.7 per cent may be expected, and in the second year 92.2 per cent.



Assembly of heating elements with extended surfaces in place

Increasing Capacity by Ribbed Elliptical Tubes

Otto Happel in the May 1941 issue of *Wärmewirtschaft* describes several recent boiler installations equipped with presteaming surfaces having ring-ribbed tubes, following the regular heating surface, in which the water is heated to steaming temperature and then becomes partly evaporated.

In the Ruhr, four bent-tube boilers have been rebuilt in this way with the ribbed-tube heating surface connected to the natural circulation of the boiler. Originally these boilers had plain-tube economizers and an output of 26,400 lb per hr, or 30,800 lb at peak load. The ribbed-tube heating surface of the rebuilt boilers (shown in the accompanying sketch) occupies only 198 cu ft each and has 4360 sq ft of heating surface. These tubes are elliptical in section and have ribs welded on at 8-mm (0.315-in.) spacing. The tube surfaces are cleaned by means of soot blowers operating with compressed air.

The author reports that these rebuilt units provide an output of 39,700 lb per hr normally and from 44,000 to 48,500 lb per hr at peak loads.

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BOOK REVIEWS

Books here reviewed may be secured through Combustion Publishing Co., 200 Madison Ave., N. Y.

Modern Marine Engineer's Manual

By Alan Osbourne, Editor-in-Chief

In view of the greatly enlarged and accelerated program in shipbuilding now being expedited by the U. S. Maritime Commission (to the tune of two ships a day), an additional host of qualified men will be needed to man them. To meet this need, licensed engineers are having their numbers augmented by new officers trained in three schools under the direction of the Maritime Commission.

Many of these engineers, particularly the older licensed men, will find the engineering equipment on these ships strange to them. Scotch boilers have been replaced by water-tube boilers, including both cross-drum sectional header and two-drum bent-tube types. Low steam pressures and low superheat have given way to higher steam pressures and high superheat. Reciprocating engines have undergone refinement and in most instances have been superseded by geared steam turbines or by turboelectric drives, while some ships have been equipped with diesel engines. Marine engineers' handbooks have been slow to reflect these changes.

It is therefore at an opportune moment that the Modern Marine Engineer's Manual appears to fill a vital need. Mr. Osbourne and his co-workers are indeed to be complimented for the completeness and lucidity with which they have covered their subjects, especially in view of the alacrity with which the book has been assembled.

Volume 1 of the Manual embraces the following subjects: mathematics and mechanics; safety, engineering materials, pipe fittings and packings; thermodynamics; combustion; boilers; boiler operations and maintenance; reciprocating engines; marine steam turbines; bearings and shaftings; lubrication; condensers; and pumps. The operator's point of view is evident throughout the text, which has been so prepared as to anticipate questions and stimulate other questions. Some errors and omissions are bound to creep into a first edition of this kind, but these are minor and do not detract from its substantial value The book is bound in flexible buckram and contains more than 1600 pages, size 5 × 7¼, and includes a 38-page index. Price $6.

Thermodynamics

By Joseph H. Keenan

The first edition of a new textbook must set its own standards of completeness and usefulness, whereas a new edition of an old one can live on past achievements. We welcome Professor J. H. Keenan's book as an outstanding contribution to technical literature and as a practical treatise for the graduate and undergraduate student. Although the emphasis is on thermodynamics rather than on heat engineering, adequate treatment is given of engines, cycles, refrigeration, air conditioning and other subjects which serve to illustrate some phase of the application of the First and Second Laws to science and engineering.

The book comprises 26 chapters which may be divided in groups for first and second term work, and also for special studies. The treatment is both concise and explicit and at the end of each chapter numerous problems, a list of symbols and a bibliography are given. A consistent simplicity characterizes the 221 diagrams which illustrate the text. No less than 334 equations are given, which indicates in some measure the broad scope of this work. The typography is excellent. The book has 499 pages including a 10-page index, and is bound in maroon cloth, size 6¼ × 9¼, and priced at $4.50.

Heat Engines, Fifth Edition

By John R. Allen and Joseph A. Bursley

The development of heat engines and their auxiliaries during the last ten years has made necessary a revised edition of this excellent textbook. The text has been largely rewritten and brought up to date with new illustrations and material.

The book comprises 17 chapters which cover more than an elementary introduction to the subject of heat engines. Beginning with chapters on heat, elementary thermodynamics, properties of steam, calorimeters, fuels and combustion, the book presents fundamental principles as an approach for the student to the understanding of the problems of steam generation. Boilers and boiler auxiliaries are then discussed, followed by a chapter on power and performance of steam engines. Three chapters deal, respectively, with steam turbines, condensers, air compressors and refrigerating machinery, while the concluding chapters deal with the internal-combustion engine, its fuel and fuel systems, ignition, cooling, etc., rating and performance.

The value of this textbook lies in the lucidity of its text, the wide range of its many illustrations and the numerous examples of the essential calculations given. Another feature is the numerous problems given at the end of many chapters. The book contains 576 pages including a 12-page index. Printed on coated stock, size 6 × 9, and bound in dark green cloth; price, $4.

Generating Stations, Third Edition

By Alfred H. Lovell

Notable advances in the field of power generation during recent years have necessitated the revision of Alfred H. Lovell's book on generating stations. Such developments include the use of steam pressures up to 2400 lb and steam temperatures up to 950 F for central station boiler units, while hydroelectric units and transmission lines of ever increasing capacity have gone into service. Radical changes in circuit protection have been effected by new designs of high-voltage, high-speed circuit breakers and high-speed relays. Hydrogen-cooled generators up to 60,000 kw rating and operating at 3600 rpm are now in service.

This edition has been revised and brought up to date by including all the significant developments of the last five years. All engineers who are concerned with or interested in the design and economics of central stations will find this an informative work.

The book contains 471 pages and is priced at $4.50.

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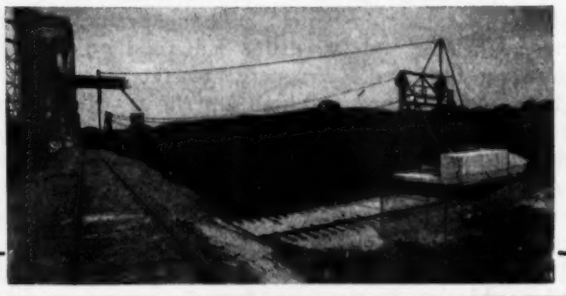
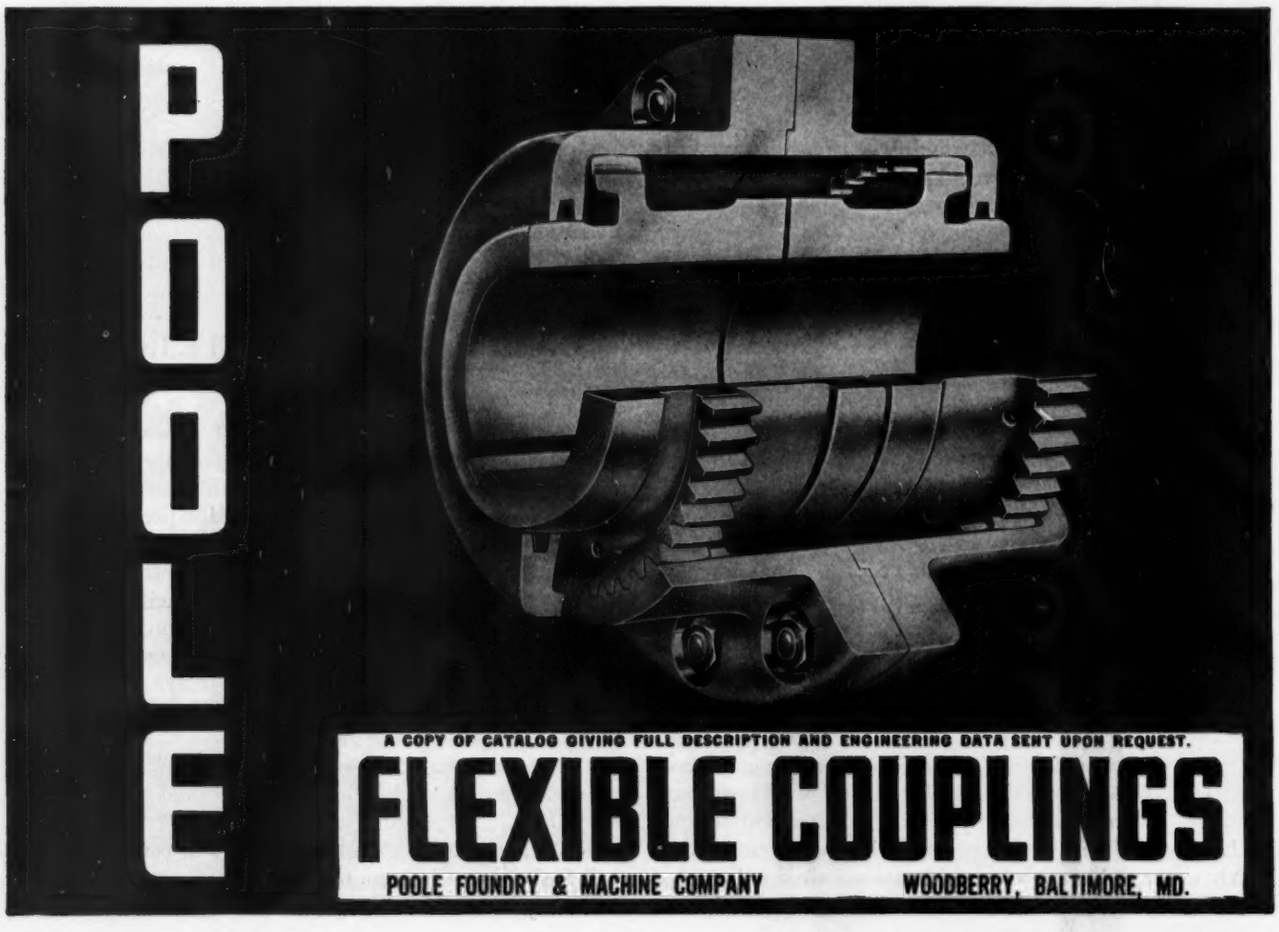
A 1 cu. yd. Sauerman Power Scraper handles the stockpile of a 25,000 KW. steam electric generating station on a ground space 320' x 200'. This installation employs steel back-posts, spaced around three sides of the storage area, as supports for a movable tail bridle. During peak periods of storing and reclaiming, the scraper handles up to 80 tons of coal per hour.

The picture below shows a 2¼ cu. yd. Sauerman Scraper unit that stores and reclaims 100 tons of coal per hour. The scraper bucket operates in radial lines between a headpost and a mobile tail tower. The tower is equipped with a motor and propelling mechanism and movement of the tower is governed by remote control from the scraper operator's station at the head end of the installation.

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Electrical Engineers Discuss Power for Defense

Speaking before the Power Group of the New York Section, A.I.E.E. on December 10, **John C. Parker,** Vice President of the Consolidated Edison Company of New York, discussed the power industry in its relation to defense, and stressed the necessity for acceptance of controlled wartime economy and planning. Power engineers, he said, can no longer expect to carry on in accustomed ways, plans must be reviewed in the light of mass production of defense articles, and many things that are normally desirable must be forgotten while the emergency lasts.

In this connection, Mr. Parker pointed out that expansion, or even maintenance of existing levels in domestic and commercial loads, must be expected to give way to the requirements of defense industries. In many cases one must be prepared to get along with uneconomic equipment and cannot expect to replace old equipment with new for efficiency alone. For example, the installation of topping units to improve the efficiency of existing plants will not be justified unless accompanied by defense demand for the capacity thus made available. Also, in determining capacity to be added to a plant, economic considerations may have to be subordinated to the possibility of aiding a neighboring utility. Furthermore, a plant or system may find it necessary to get along with less reserves in order to release capacity for other places where it is more urgently needed.

Finally, Mr. Parker was of the opinion that we are likely to have to give up for a long time the more elaborate designs, arrangements and controls, and depend upon expert operation and supervision to take their place.

The second speaker of the evening was **Ralph Kelly,** Vice President of Westinghouse E. & M. Co., who discussed the situation from the standpoint of the power equipment manufacturer. The greater part of the present expansion in electrical load, he said, is outside of metropolitan areas, the steel program alone calling for 500,000 kw additional capacity. The present demand for new steam turbines for stationary plants has superimposed on it a vast marine and naval program, the total of which will approximate 50 per cent of the present installed capacity on land. Furthermore, orders for motors have increased about 300 per cent since 1940.

Mr. Kelly stated that his company is producing approximately a million dollars worth of equipment per day and when new manufacturing facilities are completed this will be increased by at least fifty per cent. The output of power equipment alone has increased two and one-half times since 1939. This has created a large demand for skilled workers, which problem is being met by nearby vocational training schools, the student being paid by the company while learning.

He urged greater use of standard apparatus wherever possible, the elimination of gadgets and the passing up of factory tests. By such means delivery of equipment could be speeded up at least 20 per cent.

J. A. Krug, Chief of the Power Branch, OPM, was scheduled to discuss the subject from the governmental angle, but events of the past few days made it impossible for him to be present.

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Personals

D. Robert Yarnall, Vice President and Chief Engineer of the Yarnall-Waring Company, Philadelphia, was the recipient of the Hoover Medal at the Annual Meeting of the American Society of Mechanical Engineers at New York, December 1 to 5. The award was made for outstanding service as a leader in the engineering profession and for distinguished public service as a member of the mission that is now aiding refugees in this country and Europe and providing both food and relief for the children and mothers of France.

Howard W. Leitch, Vice President of the Consolidated Edison Company, New York, has retired after 46 years of service with the company and its predecessors. From 1938 to 1940 he was in charge of the company's electrical operations and since then has served as a consultant on special work.

George A. Bradley, Chief of Plants, of the Board of Water and Electric Commissioners, Lansing, Mich., will retire from active service on January 1, 1942, and will be succeeded by **George A. Abbott.**

J. V. McKinney, Executive Vice President of the Kansas City Public Service Company, has been elected president of the Iowa City Light & Power Company located at Davenport, Ia. He succeeds **R. B. MacDonald** who recently retired.

W. M. Selvey, prominent British engineer and well known personally to many in this country, has recently assumed his term of office as president of The Institute of Fuel, in London.

Howard A. Gray, who for the past year or more has been serving as Director of the Bituminous Coal Division of the Department of the Interior, has been designated by Secretary Ickes as Acting Director of Solid Fuels Coordination for National Defense.

E. R. Fish, Chief Engineer of the Hartford Steam Boiler Inspection & Insurance Company, has succeeded to the chairmanship of the A.S.M.E. Boiler Code Committee, taking the place of Dr. D. S. Jacobus who retired and who was tendered a testimonial dinner during the recent annual meeting of the Society.

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